Application of small and large-sided games to youth rugby union:

A match demands approach

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PREFACE

ABSTRACT

Rugby union (RU) is a highly demanding and a global contact sport that combines physical, technical, and tactical characteristics. This team sport is practiced by players of all ages and backgrounds on various levels of play. To meet the demands of rugby competition, a multifactorial approach to training has been applied in practice. One training method that has risen to prominence for its reported benefits of contextualising and concurrently training all aspects of high-intensity intermittent field-based sports such as RU, is small-sided games (SSG). Most research on these training forms has been conducted on soccer players and tends to confirm its benefits. Emerging evidence in the rugby codes is heavily focussed on rugby league senior players, often on the elite level. Rugby union has shown scarce evidence for SSG training in senior players, but the knowledge regarding youth players is lagging. The aim of this thesis was therefore to investigate the application of SSG to RU, clarify their characteristics in youth players, and evaluate their suitability in function of developing and preparing players for competition.

The initial literature review in Chapter 2 outlines that the physical, physiological, and kinematic demands of rugby competition are high, and vary according to the cohorts investigated, such as for playing level and position. In addition, emerging evidence showed that the match demands of youth differ between age groups, and from those in senior players. This preliminary investigation showed scant evidence of SSG efficacy and utility for improving physical performance but the research regarding the effects of SSG design was scarce and demonstrated incoherent methodology. The systematic review of the body of literature in Chapter 4 used PRISMA methodology to establish that five out of seven initial studies examining the effects of SSG were at critical risk of bias, and a further two were at moderate risk. Despite moderate to good methodological quality (52-98%), these findings imply two studies provide sound evidence for a non-randomized study but cannot be considered comparable to a well-performed randomized trial, and five studies are objectively too problematic to provide any useful evidence and should not be included in any future synthesis of the literature. Within these studies, the lack of a focussed line of investigation was identified as a key weakness. Initial results of the review indicated that various SSG designs influence the outcomes differently for different cohorts, and that fewer players and larger pitches could increase demands. However, no evidence was available for the design of SSG in youth RU players. Recent evolutions in the relevant literature revealed that seven additional studies have expanded the knowledge but show a similar disparity in methods, hampering the ability to extrapolate clear and applicable conclusions for SSG design, especially in youth players.

In Chapter 5 and Chapter 6, a worldwide e-survey study (n=115) discussed the application of SSG in RU practice. These results confirmed the notion that SSG are widely used in practice, with 85% of practitioners, applying SSG regularly across all levels of play and in all age categories. Technical skill (26%), fun (25%), physical conditioning (18%), and tactical training (17%) were established as the main targeted objectives. The specific design of SSG was related to practitioners' characteristics such as playing level, coaching experience, practitioner role, target age group, player sex, and geographical location. Most practitioners used two or three bouts of three to seven-a-side SSG, with a 1:1 to 5:1 work-rest ratio, for short durations (2-10 minutes). Tackle (37%), touch (36%), and wrapping (28%) were commonly implemented rules. However, school and lower-level coaches used longer bouts and tackle rules on less variable pitch sizes, for fun and technical skill, more often than higher-level coaches, who preferred shorter-duration bouts with touch rules and more extreme pitch sizes, primarily for physical conditioning. Overall, 3v3, 5v5, and 7v7 were determined to be the most popular top-three SSG formats. We established that SSG design should be evidence-based and reflect the needs and challenges of the specific performance context.

In Chapter 7, a cross-sectional experimental study was conducted on NZ secondary school-age RU players (n= 158; age 14.8 ± 1.4; height 174.5 ± 7.5 cm; mass 77.2 ± 17.1 kg). Four age groups (U14, U15, U16, U18) randomly played 3v3, 5v5, or 7v7 on a small (S= 25x35 m), medium (M= 35x50 m), or large (L=50x70 m) pitch, for three bouts of four minutes with three minutes of active recovery. Kinematic, physiological, and physical data were captured using microsensor devices, alongside ratings of perceived exertion (RPE) and injury incidence. Multiple multivariate and univariate analyses found that player number and pitch size are the main elemental SSG design factors driving performance outcomes, followed by player age category and bout sequencing. The results showed that the isolated effect of increasing player numbers decreased kinematic and physiological demands, while an increase in pitch size mainly increased kinematic but not physiological demands. However, design factors mutually affected each other's influence and select performance measures, such as sprint frequency, showed greater resistance to changes in format.

Moreover, the innovative approach of the study in Chapter 7 integrated the SSG design constraints and demonstrated that maximising relative playing area (i.e., 3v3-L) maximises most kinematic, physiological, and physical performance measures. These findings further suggested that various SSG formats between ~350 and 583 $m^2 \cdot player^{-1}$, and for some measures as little as 175 $m^2 \cdot player^{-1}$, can produce running demands of approximately 94 $m \cdot min^{-1}$ of relative distance (RD) and 145 m of high-intensity running distance (HIRD).

Intensity measures across all youth showed an RPE of 15 and an average heart rate (HR_{AVG}) of ~83% HR_{MAX} for the highest-reaching full SSG format (3v3-L). Nevertheless, only 1.1 ± 1.2 minutes per bout and 4.3 ± 3.8 minutes per SSG (~24%) were spent above 90% HR_{MAX}, an intensity often deemed necessary for promoting cardiovascular adaptation. Bout 1 was shown to yield greater performance than subsequent bouts, mainly in formats with the most extreme relative pitch sizes. However, RPE increased with every bout in all SSG formats. Differences between age groups were identified that were performance measure-specific, non-linear in evolution, and non-uniform. A conservative injury incidence of 59.8 per 1000 player-hours was found.

The match demands of rugby sevens (7s) were investigated in Chapter 8, showing a continuous high-intensity profile. Youth players demonstrated high kinematic demands with RD of ~111 $m \cdot min^{-1}$, ~3 $sprints \cdot min^{-1}$, and ~252 m HIRD. Match intensity resulted in an HR_{AVG} of ~90% HR_{MAX}, with up to 58% of game time above 90% HR_{MAX}. These youth match demands were established to be greater than their international peers, senior 7s games, and elite-level cohorts. Of note, U15 demonstrated greater kinematic and physiological demands than their U19 counterparts. In Chapter 9, the demands of fifteen-a-side matches were investigated, showing a more intermittent high-intensity profile. Approximately 87% of match distance was covered at low speeds (<50% V_{TOP}) with an HR_{AVG} of 87% HR_{MAX}, and up to 88% of game time was performed above 80% HR_{MAX}. Kinematic demands showed ~73 $m \cdot min^{-1}$ of RD, ~1.4 $sprints \cdot min^{-1}$, and ~410 m HIRD. Performance was largely maintained between playing halves and differences between forwards and backs mainly related to relative performance. These demands converged towards and even surpassed those of the senior game and some elite-level cohorts.

In conclusion, this doctoral thesis contributes novel evidence to the body of knowledge that deepens the understanding of the application of SSG to youth RU players, relative to match demands in 7s and fifteen-a-side matches. This knowledge is important as it provides a standardised benchmark to apply concrete SSG guidelines for targeting general and specific outcomes in RU practice. This benchmark can be used to contrast with higher-level competition demands and thereby forming the foundation of a developmental pathway by progressively targeting these performance standards. Based on our research, standardised SSG with greater relative pitch area generally increase acute kinematic, physiological, and physical demands in U14 to U18 RU players. However, important nuances exist between individual performance measures on the one hand, and between age categories on the other. These nuances require further research and SSG prescription necessitates an age group and outcome measure-specific approach (i.e., exact physical, physiological, kinematic, technical and/or tactical variables), which can be optimised by practitioners implementing constraint manipulation within their specific context.

The kinematic, physiological, and physical match demands of NZ secondary school-level competition are very high and may adequately prepare players for senior and higher-level rugby. Small-sided game training as delivered in this investigation can be used as a safe and solid basis for general conditioning of youth players and to prepare them for most movement demands of RU competition. To obtain optimal match preparation, SSG design should be modulated using the prescriptions presented in this thesis and expanded on by experimenting with additional design elements taken from best-practice, cross-code, and cross-sport SSG research. To meet full competition demands, SSG training should furthermore be complemented by other training modalities to attain the requisite and complete high-intensity cardiovascular and movement performance outputs of fifteen and seven-a-side youth rugby competition.

ACKNOWLEDGEMENTS

I can remember sitting on my parents' bed one day, a very long time ago. My brother and I were learning about biology with our mother, and I found myself thinking something along the lines of: *"this science stuff is pretty cool, maybe one day I can become a researcher of kinds in a faraway country..."*. Many years have passed, and many roads have been travelled, since. I have gotten up one more time than I have fallen down. Here I find myself still becoming. And I find myself trying to think of the right words to close the most challenging academic project, life project, really. The truth is, I will not find the perfect words, nor will I ever fully become. One thing is clear to me, however; it has been one enormous journey for which I owe a word of gratitude.

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It has taken a Team to attain something extraordinary. Thank you for being on my team. Onwards we go!

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

ESM =	Electronic supplementary material
SSG =	Small-sided games
TGfU =	Teaching Games for Understanding
RU =	Rugby union
SSG^{RU} =	Rugby union Small-sided games
RoB =	Risk of bias
CONSORT =	Consolidated Standards of Reporting
PRISMA =	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
PROSPERO =	International Prospective Register of Systematic Reviews
NRSI =	Non-randomised studies of intervention
RCT =	Randomised controlled trial
ROBINS-I =	Risk of bias in non-randomised studies of intervention
PICOS =	Patient/Population/Problem – Intervention – Comparison – Outcome – Study type
RPE =	Rating of perceived exertion
HR =	Heart rate
GPS =	Global positioning system
ES =	Effect size
HR_{AVG} =	Average heart rate
$\%HR_{MAX}$ =	Percentage of maximal heart rate
HR_{Z} =	Heart rate zones
V_{AVG} =	Average speed
V_{REL} =	Relative speed
V_{MAX} =	Maximal speed
CI =	Confidence interval
$HR_{RECOVERY}$ =	Recovery heart rate
HRR =	Heart rate reserve
HSR =	High-speed running
G =	Impacts per intensity zones
LSD =	Low-Speed Distance
HSD =	High-Speed Distance
MSS =	Maximal Sprint Speed
Acc_{MEAN} / Dec_{MEAN} =	Mean acceleration/ deceleration
TF =	Tight forwards
LF =	Loose forwards
SH =	Scrum halves
IB =	Inside backs
OB =	Outside backs
FB =	Feedback
NFB =	No feedback
Y =	Yes
N =	No
GYRO =	Gyroscope
NS =	Not specified
V_{Z} =	Speed zones
V_{PEAK} =	Peak speed
TD =	Total distance
RD =	Relative distance
U(x) =	Under (age group)
Yrs/y =	Years
NS =	Not specified
HIIT =	High-intensity interval training
TEC =	Traditional endurance conditioning
GBT =	Game-based training
NA =	Not applicable
L =	Low (RoB) / Large (size)
M =	Moderate (RoB) / Medium (size)
S =	Serious (RoB) / Small (size)

C =	Critical
NI =	No information/incomplete information
VA =	Video analysis
PI =	Predictor Importance
$TRIMP_{mod}$ =	Stagno heart rate training impulse
AU =	Arbitrary units
RPE-L/RPE-B =	Differential ratings of perceived exertion for leg muscle exertion and breathlessness
School level =	Representing school teams / competing in school competition
Local level =	Representing specific geographically localised areas / competing in amateur leagues (e.g., cities, towns, villages, communities)
National level =	Representing (semi-)professional clubs / competing nationwide (e.g., NPC, Gallagher Premiership)
Professional level =	Representing professional clubs / competing in (inter)national club competitions (e.g., Super Rugby, PRO14)
International level =	Representing countries / competing on the world stage
GBT =	Game-based training
GBA =	Game-based approach
HC=	Head Coach
S&C =	Strength and Conditioning coach
AC=	Assistant Coach
NZ =	New Zealand
U(x) =	Under (age group, e.g., U18)
W:R =	Work-to-rest ratio
V_{TOP} =	Top speed
7s =	Rugby sevens
RL =	Rugby league
HIRD =	High-intensity running distance
HSRD =	High-speed running distance
VHSRD =	Very high-speed running distance
HIacc =	High-intensity acceleration
HIdec =	Hi-intensity deceleration

DOCTORAL THESIS RESEARCH OUTPUTS

Journal publications

Wintershoven K., Beaven M.C., Gill N.D., & McMaster T.D. Prevalence and implementation of small-sided games in rugby union: a preliminary survey study. *The Journal of Sport and Exercise Science* 2023; 7: 1-11. DOI: 10.36905/jses.2023.01.01.

Wintershoven K., Beaven C.M., Gill N.D., & McMaster, T.D. New Zealand Youth Rugby Sevens: A Comparative Match Demands Study. *Journal of Functional Morphology and Kinesiology* 2023; 8: 41. DOI: 10.3390/jfmk8020041.

Wintershoven K., Beaven M.C., Gill N.D., & McMaster T.D. How coaches design small-sided games in rugby union: a practice-based review. *Movement & Sport Sciences - Science & Motricité* 2023; 23 (123):71-84. DOI: 10.1051/sm/2023021

Wintershoven K., Beaven, M.C., Chan D.K.E., Gill, N.D., & McMaster T.D. The influence of elemental small-sided game design factors on kinematic, physiological, and physical performance markers in secondary school-level rugby union. *Journal of Sport Sciences*. (Under review).

Wintershoven K., Beaven M.C., Gill N.D., & McMaster T.D. U19 rugby union match demands: a New Zealand school-level perspective. *Journal of Australian Strength and Conditioning*. (Under review).

Academic conference presentations

K. Wintershoven, Beaven M. C., Gill N.D., and McMaster T. D. The reality of small-sided games in rugby union (2019). Presented at the University of Waikato Arts, Law, Psychology, and Social Sciences (ALPSSGRAD) Conference, Hamilton, New Zealand (Oral presentation).

K. Wintershoven, Beaven M. C., Gill N.D., and McMaster T. D. The reality of small-sided games in rugby union (2019). Presented at the Australasian Skill Acquisition Network (ASAN) Annual Conference, Hamilton, New Zealand (Oral presentation).

K. Wintershoven, Beaven M. C., Gill N.D., and McMaster T. D. The reality of small-sided games in rugby union (2019). Presented at the Sports and Exercise Science New Zealand (SESNZ) Annual Conference, Palmerston North, New Zealand (Oral presentation).

K. Wintershoven, Beaven M. C., Gill N.D., and McMaster T. D. The Reality of Small-Sided Games in Rugby Union - A case for systematic approach (2020). Presented at the European College of Sport Science (ECSS) 25th Anniversary Virtual Congress (Pre-recorded oral presentation).

K. Wintershoven, Beaven M. C., Gill N.D., and McMaster T. D. The impact of Small-Sided Conditioning Games on Rugby Union Youth (2020). Presented at the Sports and Exercise Science New Zealand (SESNZ) Annual Conference, Christchurch, New Zealand (Oral presentation).

K. Wintershoven, Beaven M. C., Gill N.D., and McMaster T. D. The pathway to an Olympic medal: A comparative youth rugby sevens match analysis (2021). Accepted for the Sports and Exercise Science New Zealand (SESNZ) Annual Conference, Auckland, New Zealand (cancelled due to COVID 19 restrictions).

K. Wintershoven, Beaven M. C., Gill N.D., and McMaster T. D. On route to the Olympic podium: A comparative youth rugby sevens match analysis (2022). Presented at the European College of Sport Science (ECSS) 27th Annual Congress, Seville, Spain (Oral presentation).

Manuscripts in preparation for (re)submission

K. Wintershoven, Beaven M. C., Gill N.D., and McMaster T. D. Small-sided games in rugby union: A systematic literature review and risk of bias assessment.

Wintershoven K, Beaven, M. C., Chan D. K. E., Gill, N. D., & McMaster, T. D. The acute kinematic, physiological, and physical demands of standardised small-sided games in rugby union adolescents.

Wintershoven K, Beaven, M. C., Chan D. K. E., Gill, N. D., & McMaster, T. D. The effect of small-sided game bouts on kinematic, physiological, and physical performance measures in rugby union adolescents.

STRUCTURE OF THE THESIS

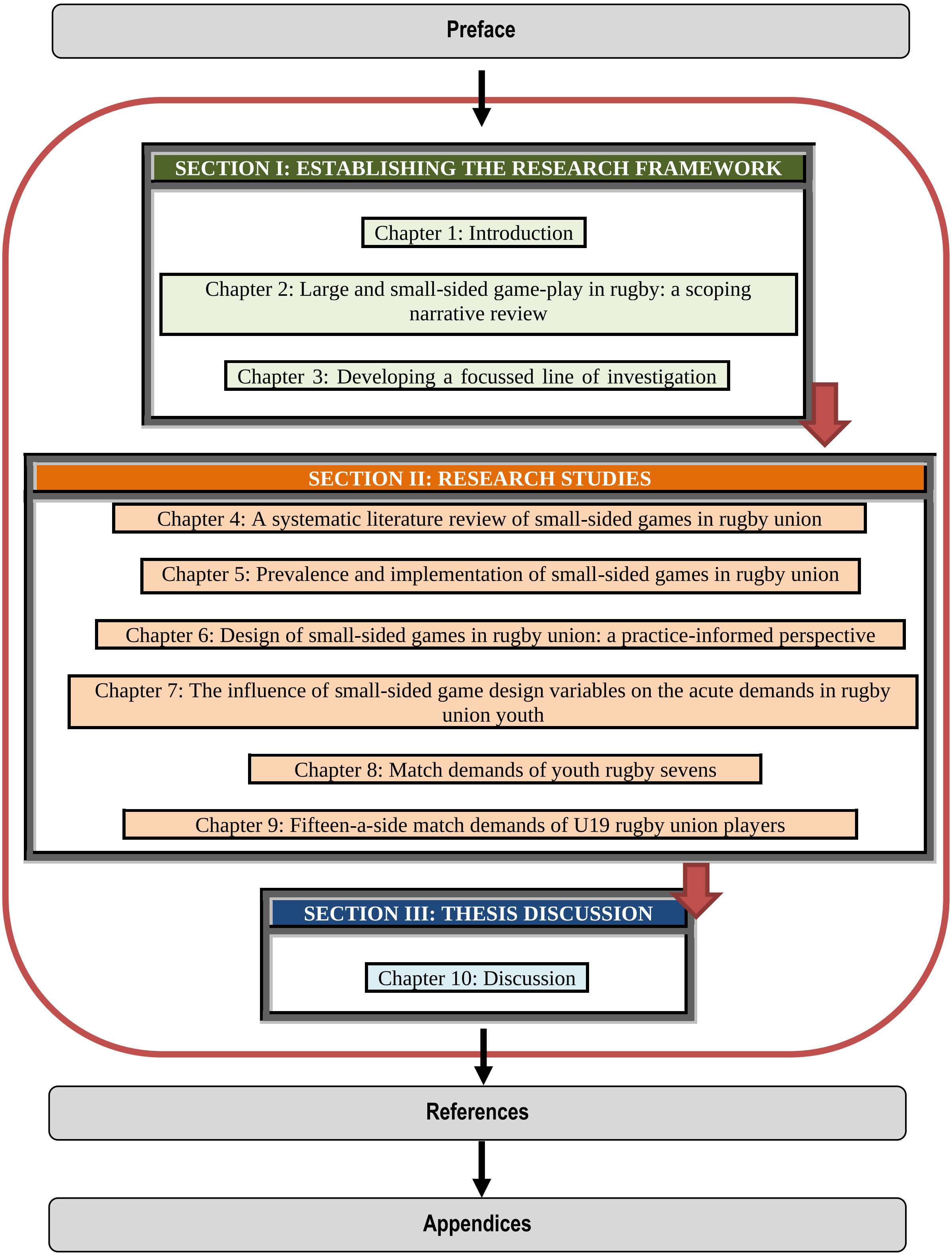

Figure 1 Thesis structure

SECTION I

ESTABLISHING THE RESEARCH FRAMEWORK

CHAPTER 1

Introduction

Chapter prelude

To investigate the application of small-sided games (SSG) to rugby union (RU), it is useful to understand the context in which this research topic is situated. Therefore, this chapter will investigate the history of the sport and the general background of training and SSG, to situate the meaning of this doctoral research.

1.1 A brief history of rugby

1.1.1 Introduction

The generic term "Rugby" is the commonly used to refer to the sport of RU, one of several rugby football codes. Rugby football is a full-contact team sport in which an oval ball is passed, carried, or kicked to gain points, and tackles are permitted to prevent the opposition from scoring [1, 2]. Originating from their pre-industrial British folk game-antecedents in the nineteenth century, 'rugby football', together with 'soccer', emerged gradually as the two main forms of "football" [3]. It is believed that the sport of rugby was conceptualised at Rugby School in the English town of Rugby, around 1823 [4]. This more traditional fifteen-a-side game is considered the original format [1, 5]. A distinction can be made with rugby league, a similar but not identical, thirteen-a-side game. Both are heavily historically intertwined [3, 6, 7]. Among the other variants and derivatives, also recognised within the rugby football codes, are Australian football (AFL), American football (NFL), Gaelic football, touch rugby, rugby tens, and the Olympic discipline of rugby sevens [1, 5, 8, 9].

1.1.2 Rugby union participation

Rugby is played in one hundred and thirty-two countries around the world, incorporating associate and member unions distributed across all continents [10]. Ranking in the top three team contact sports globally, it is one of the most played and well followed sports in the world [11-13]. This global reach is the result of a strong commitment from World Rugby, the international governing body formerly known as International Rugby Board (IRB), through global investment; £69 million for 2017 and an overall periodical increase from £153 million between 2009 and 2012 to a record £266 million for the period of 2016-2019. A growing revenue from £1 million in 1987 to £122.4 million in twenty years further underlines the financial magnitude of World Rugby. The impact of this is seen in new territories and across demographics in emerging markets such as China, Russia, Pakistan, Kenya, Chile, and the Caribbean [11-13].

Rugby participation grew from an estimated 9.1 million players worldwide in 2017, to 9.6 million players in 2018 and 2019. In 2021 following the global COVID-19 disruption, rugby re-established itself with 7.6 million participants, 4.2 million of which were registered as active players with a recognised team. Almost a quarter of the total playing population are female participants, as compared to nearly one in three in 2017 [14]. In spite of the challenges endured in recent years, rugby stands strong with new growth seeing participation currently approaching 10 million players in member unions globally [10].

As discussed, rugby's origin can be traced back to England, where the game is still an integral part of society and is certainly part the educational pathway [4, 6, 7, 15, 16]. Unsurprisingly, England therefore has the highest participatory numbers in the world by a substantial margin, followed by the United States of America and France (Table 1) [13]. The widespread geographic location of these top three countries is somewhat of a testament to the global nature of rugby. What is more, the game of rugby reaches a wide basis of many different nations with varied social, cultural, economic, and political characteristics (Table 1**Error! Reference source not found.**). The net growth realised in participation in years past, was realised through continuous initiatives from World Rugby to get more people involved and further globalise the impact of this sport [12, 14].

Table 1 Top 10 nations with highest player numbers (Source: World Rugby - Annual Reports, 2017)[17]

Country	Total Player number	Players/ 100 capita
England	2.116.897	3.21
USA	1.529.965	0.47
France	604.440	0.90
South Africa	603.455	1.06
Australia	548.403	2.23
Japan	266.898	0.21
Fiji	222.583	24.58
Canada	215.624	0.59
Ireland	195.744	4.09
Brazil	185.155	0.09

1.1.3 New Zealand rugby union

Rugby was introduced as leisurely gameplay to New Zealand (NZ) by immigrants in the 1860s and evolved into the competitive sport it is today, rooted in New Zealand's history and society [18-20]. The NZ rugby team (the All Blacks) were the first Rugby World Cup Champions (1987) and are the only team to successfully defend their title (2011, 2015) for an overall total of three Rugby World Cups won. This feat stands a unicum in rugby. With 155,934 participants nationwide for the year of 2017, NZ sits at a twelfth place, behind Scotland (180,534). At 3.25 players per 100 capita, however, New Zealand ranks amongst the highest relative participants. As in several other countries, rugby is an integral part of NZ society, manifesting itself in many forms and on many different levels [21]. These facts further underline the role rugby plays worldwide, and the potential it has to reach people everywhere.

1.1.4 The demands of rugby union

The sport of rugby has been described as a highly demanding game of long-duration, consisting of intermittent high-intensive actions, incorporating many physical, technical, and tactical components, which require a multifactorial approach with contextual differentiation regarding competition, playing level, age, position, and training approach [2, 22-29]. Despite the challenging nature of rugby, it is easy to understand that the different components of this game and the various forms it has evolved into, can have a considerable appeal to the growing population involved. World Rugby thereby strives to make the game more accessible to the wider public through offering a range of modifications and competitions [30, 31].

Somewhat conversely to its popularity, since the start of the professional era in rugby in 1995, a parallel debate has raged concerning the exposure of players to the rigours of rugby [11, 32]. In the United Kingdom this culminated in a 2016 open letter from academics and medical doctors directed towards their respective British ministers, on which the popular media BBC reported [33]. As a consequence of the questions raised and stances taken in search of clarifying injury incidence, the nature, causation, patterns, severity and types of injuries that occur due to rugby's inherent characteristics, the development of preventative strategies and the optimisation of player preparation has been pursued since [34-38]. In that regard, it has been postulated injury incidence is related to decreased levels of skill and fitness [39]. In accordance with this, World Rugby acknowledges the importance of adequate preparation, both mentally and physically, and endorses the application of such programmes to rugby [40].

1.1.5 Summary

We can hereby conclude that rugby is a globally popular and impactful sport, rooted in a rich history. Rugby is an interwoven part of NZ's culture and society, and the All Blacks, arguably the most successful team in history, have become an inherent part of the country's identity. The demands of the sport are multiform and entail a complex set of challenges. Preparation is key for players to optimally play and enjoy the game. Moreover, research has shown well-balanced training load and a range of well-developed physical qualities are conducive to the players' health and performance [22, 23, 41-43]. A strong case can therefore be made for optimising development and monitoring of the overall fitness of rugby players.

1.2 Small-sided games

1.2.1 Introduction

Small-sided games have been lauded to be an effective and time efficient sport-specific form of aerobic interval training to concomitantly improve various technical and tactical characteristics [44-47]. Many different sports have reportedly adopted them as common training practice. Consequently, SSG have been investigated to gain a better understanding of their effects and the underlying mechanisms, aimed at optimising conditioning in an array of different team sports, including soccer [48, 49], handball [50], lacrosse [51], hurling [52], basketball [53], volleyball [54], Australian football [55], and rugby league [56, 57], as well as generic games [58].

1.2.2 Research

The research methodology used to investigate SSG and its associated variables has generally been inconsistent. Despite large variations in the design of SSG, predominantly soccer-related research has led to establishing certain trends regarding the influence of player numbers, field size, and the presence of coaching [46, 48, 49, 59, 60]. The inconsistent designs, however, make it difficult to draw clear conclusions. Indeed, the effects of manipulating individual variables of SSG on the physical, physiological, kinematic, technical, and tactical outcomes of SSG is not entirely understood [46, 56, 61]. Nevertheless, researchers have explored various frameworks such as Teaching Games for Understanding (TgfU) and constraints-led coaching to explain the utility of and the mechanisms through which SSG operate [62-64].

1.2.3 Application

The importance of SSG as a form of sport-specific training in the developmental pathway is further buttressed by its ability to optimise the development of aerobic fitness in various contexts, alongside technical and tactical attributes in team sport players, if accurately prescribed [61]. As such, SSG can be conducive during the *sampling stage*, alongside other moderate-intensity sport-specific drills and activities, and play a primordial role for high-intensity training in the *specialisation stage* and the *investment stage* [61]. An apparent need for more descriptive training studies regarding game-based training (GBT) has furthermore been indicated in the literature, as limited evidence exists regarding the procedures in different contexts to optimise developmental outcomes in practice. [61].

1.2.4 Conclusion

As rugby has become a global sport which is rooted in history, its expanding impact now reaches across populations, cultures, and ages [6, 10, 14, 20, 21, 65-67]. The sport is an integral part of the English and New Zealand society, and the educational and development pathways, among others [6, 18, 19, 65, 68]. The match demands in RU have been investigated, leading to training recommendations, yet often focussing on elite-level and professional players [23, 24, 26, 69]. The demands of RU at younger ages, be it at university, academy, or school level, seem to differ markedly from those of the senior game [16, 24, 26]. Nevertheless, little is known about youth-specific preparation for those demands. Despite the favourable evidence on GBT, a dearth of research has focussed on rugby union SSG (SSG^{RU}) specifically. Moreover, no guidelines are available for applying SSG in RU, especially on the youth level.

1.3 Rationale for the research

1.3.1 Significance of Rugby

A review of the existing literature shows that the sport of rugby football has made a mark in history, and that rugby has a growing share in global sports. There are several aspects that are of importance that will be outlined in the following synthesis.

Today, rugby is a globally played sport with a growing player population [70]. Rugby is played in all layers of society, including the educational system and as a means of leisure, as demonstrated by (school-level) participation numbers, and training and injury prevention efforts, nationally and internationally [34, 38, 71-75]. Increasing player numbers are found over a varied geographical, social, economic and gender range. Therefore, the international governing body, World Rugby, invests heavily in the development of global rugby.

Professionalism has led to increasing performance standards and higher game demands, which has resulted in a more in-depth approach to the sport. Concurrently, there has been a clear increase in attention to, and an intensifying debate about, the overall physical integrity of players, and consequently the preparation of players for the rigours of the game.

Overall, it can be concluded, rugby is a highly demanding sport with a 6% to 90% probability of injury for players under 21 years of age during a RU season [22, 74]. These relatively high demands and injury risk can be moderated by adequate training programmes and preventative strategies, and are associated with playing level, age, and other potential risk factors such as training load, ethnicity, injury history, and playing environment [15, 43, 76-78] A dependency on definition and methodology is also evident [11, 79, 80]. Nevertheless, rugby is a global phenomenon with a wide reach and growing ambitions. An important role is laid out for preventative and preparative mechanisms through physical conditioning and training, for player development and performance optimisation.

1.3.2 The relevance of small-sided games

Rugby has been well-established as being a "highly demanding physical, tactical, and skill-based team sport" [23]. The intermittent high-intensity contact nature of rugby places several specific physical and physiological demands on the players [24, 26, 81]. Although differentiation is of the essence, to address these demands, players are required to develop a specific athletic profile to adequately tolerate the rigours of rugby and be successful [16, 24, 26]. Among many methods, SSG are used to train and develop athletes.

Small-sided games are stated to be widely used in team sports [46]. Research pertaining to SSG has increased drastically over the last two decades, demonstrating its popularity and feasibility as an effective training method for team sport preparation [45-48, 82, 83]. The benefits of SSG are two-fold, firstly for physical conditioning, and secondly for the development of sport specific skills. SSG also provide the modifiable context and training stimuli needed to adequately prepare players for the intermittent high-intensity activities characterising rugby [61, 84, 85]. These characteristics make SSG an efficient training tool for coaches and practitioners, alike.

The relatively large body of research on SSG in team sports has mainly focussed on soccer [46, 48, 59, 86]. In this body, a lack of structure has been reported to impede an optimal evolution of understanding [49, 60]. A limited amount of research has thereby been conducted with regards to the effects of SSG in RU [86-89]. Additionally, physical and movement demands of youth RU play have been reported to differ from senior play [16]. Notwithstanding, game characteristics are extrapolated from the latter to serve as a standard, they may not be representative for all RU play at the youth level [23]. To the best of our knowledge, at the onset of this doctoral study, no research had been conducted with regards to SSG in RU below the senior level and across the playing levels. The ability to provide an evidence-based training modality to optimise the development and conditioning of youth and senior RU players, was a major driver of this research project.

1.3.3 Importance for advancing knowledge

The following elements make an **original contribution to the existing body of literature**:

- ***Evidence*** of alleged ***in-practice use of SSG*** as a training form in RU (***SSG^{RU}****)*.
- **Systematic** mapping of the ***current state of the evidence*** in ***SSG^{RU},*** *including* ***risk of bias***.
- ***Establishing*** a ***RU-specific SSG definition*** for practitioners'
- ***Determining popular*** in-practice ***SSG^{RU} formats***.
- Combined mapping of ***physical, physiological, and kinematic demands*** in ***SSG^{RU}***.
- Exploration of demands of specific ***SSG formats*** with ***youth*** RU players ***across*** different ***levels/age groups of play*** in New Zealand.
- Exploration of the ***overall importance of elemental design factors*** for SSG^{RU}, ***based on a large pool of outcome variables***.
- Exploration of the physical, physiological, and kinematic ***effects of SSG training bouts*** in RU.

- Inclusion of ***unexplored outcome measures*** for ***youth*** **SSG**^{RU}; i.e., relative speed zones, average heart rate, injury incidence.
- Integrated mapping of ***fifteen-a-side and seven-a-side match demands*** in New Zealand youth.
- ***True randomisation*** of subjects into conditions (i.e., SSG).
- A ***standardised structured approach to research design*** where previous research has failed to uphold consistent design:
    - SSG playing area (cf. full pitch size - 10/7 ratio),
    - Coaching (not allowed),
    - The use of optimised, practically relevant speed metrics (e.g., % maximal speed).
- Physical, physiological, and kinematic demands for training and match play from ***the same cohort***, in various levels/age categories of play.
- ***Prescriptive guidelines*** for application of SSG in function of level/age-specific RU and sevens match play and development.

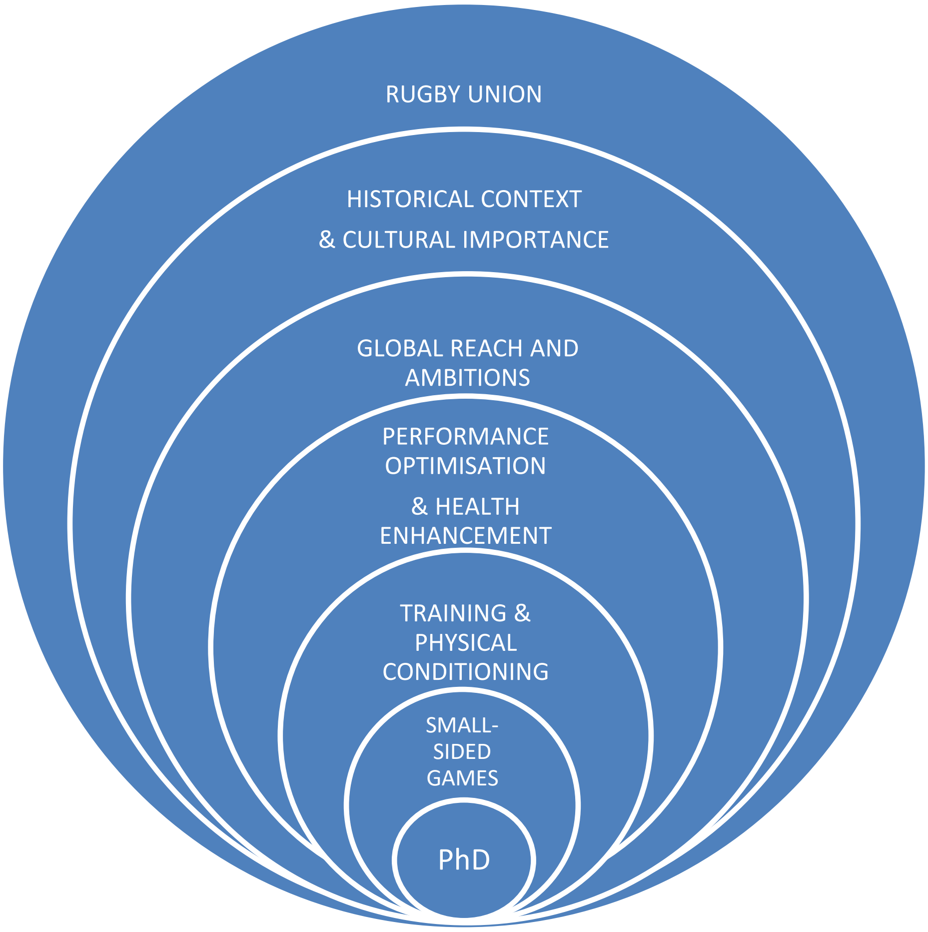

Figure 2 Significance of doctoral research

1.4 Thesis aims

The Thesis aims are predicated on the following observations:

- The reported widespread 'best-practice' use of SSG as a training tool in sports,
- The limited amount of research into SSG game play in RU specifically,
- The lack of knowledge regarding SSG play in RU youth players,
- The lack of clarity regarding the relationship of SSG play across RU age/playing levels,
- The relatively recent efforts to start expanding the data on RU training and match demands below the senior level,
- The importance of SSG in the developmental pathway,
- The ongoing debate about player safety in rugby play.

The purpose of this thesis was therefore:

> To improve the current understanding of SSG application to RU, by investigating the relevant body of knowledge, the application by practitioners, and the physical, physiological, and kinematic variables of several SSG and full match formats, in the available male RU youth and adult players.

The sport and cohort-specific insights into RU training and match demands add to the relevant body of knowledge and serve to formulate guidelines and goals for youth development towards optimal youth and senior game performance. The novel approach in this study may serve as a base for researchers to conduct cumulative research in this area, to further map out the effects of various SSG design variables in a structured manner.

Statement of research intent:

With this doctoral study I have investigated the application of small-sided games to male rugby union players, by studying the different aspects of their implementation in theory and practice, in an effort to progress the understanding of these training forms, for contributing to evidence-based training and to form a solid basis for further structured research.

CHAPTER 2

Large and small-sided game-play in rugby: a scoping narrative review

Chapter prelude

Chapter 1 outlined the significance of RU in history and society. A preliminary view was given on SSG and how this training method has been relevant in field-based team sports. Considering the gaps in knowledge that seem to emerge in rugby, and youth RU especially, Chapter 2 will formally investigate large and SSG play in rugby to confirm the initial rationale and form a more complete picture.

2.1 Introduction

Historians have narrated the history of rugby union (RU) based on the available records and accounts. The exact details of rugby's conception are not precisely documented, but they are part of the folklore and charm of the sport. A gradual development has taken place across the ages, growing into a rich history interwoven with other football codes. This development has giving rise to the global sport of RU, which now reaches across the world in terms of socio-economic impact and participation [3, 4, 6, 7, 10, 12, 20, 90]. In New Zealand, it is likely that several forms of leisurely rugby gameplay were introduced by immigrants in the 1860s. The first RU game was formalised between the Nelson Club and Nelson College in 1870, and from there on the game has become rooted into various aspects of New Zealand's historical and societal development, eventually becoming part of the country's identity [18-20].

The body research at large has described RU as a field-based team sport that is highly demanding and of an of an intermittent nature, while also incorporating physical, tactical, and skill-based components [22, 23, 26]. In the last two decades various facets of the different forms of rugby have been analysed repeatedly for several cohorts [22, 26, 28, 91-95] . Reports in the literature of 180 bpm HR, maximal blood lactate levels of up to 9.8 $mmol \cdot L^{-1}$, and 72% of match time performed above 85% of HR_{MAX}, indicates that players are stressed on a musculoskeletal and cardiovascular level, taxing both the aerobic and anaerobic system while also being required to effectively manage various skill and tactical tasks [22, 41, 42].

As a consequence, preparation is an essential aspect for rugby performance. Within this multifactorial field, small-sided games (SSG) have experienced a surge in the football codes literature and has made its way into the rugby codes [46-48, 83, 96, 97]. The aim of this study was therefore to explore and summarise the relevant body of literature regarding the characteristics of large and small-sided rugby game-play, to identify important aspects and create a framework that could serve for further in-depth research. To this purpose, an unstructured review was performed using Scopus and Google Scholar.

2.2 Rugby characteristics

2.2.1 Match demands

Rugby is a multi-facetted game. Studies have consequently labelled rugby at large, and thus RU, a highly demanding physical, tactical, field and skill-based team sport, with intermittent characteristics demanding frequent bouts of high-intensity activity and collisions [23, 26]. Though differentiation is key within and between player positions, playing level, age, and between game codes, specific physical and physiological characteristics are essential for rugby performance [22, 26, 42, 92, 95, 98-102]. These characteristics include a relatively high body and lean muscle mass, which is similar between RU and rugby league (RL) players, yet typically greater than found for international players of other team sports like soccer, field hockey, and basketball [22].

Across RU competition levels, mean height and body mass values vary from around 80 kg and 1.75 m on the lower end in backs, to more than 120 kg and 1.99 m in forwards at the elite level [22, 42, 92, 95, 98-102]. Low to moderate levels of body fat (~8 to 17%), near-even slow to fast twitch fibre distribution (~45/55% respectively) and a relatively high maximal oxygen uptake (VO_{2MAX}) are typical for elite-level and professional players (~50-63 mL/kg/min) [22, 42]. On amateur, junior, or sub-elite levels, significantly lower VO_{2MAX} (-20 to -42%) are reported [42]. High strength and power output are furthermore critical during game phases with very high mean peak forces, like scrummages (6210 - 9090 N) [103]. Regarding lower-body power, vertical jump height (Figure 3) has been demonstrated to differentiate between performance levels, as well as playing positions [22, 42, 98, 102].

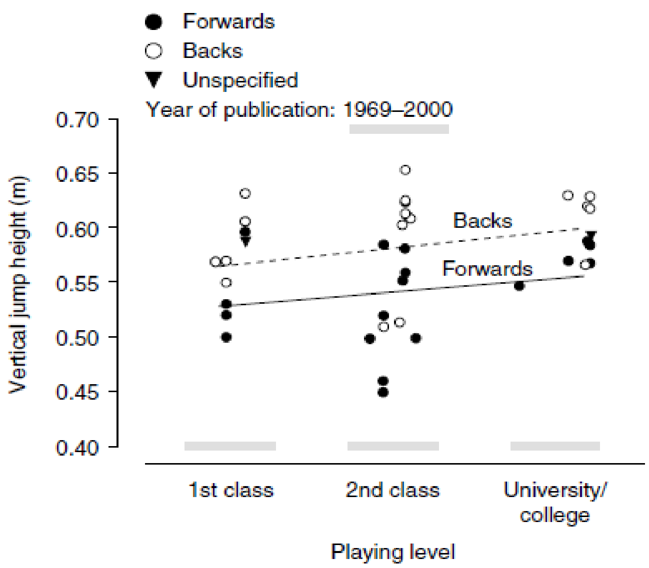

Figure 3 Vertical jump height (m) of rugby union players [source: Duthie et al. (2003)][22]

The player characteristics serve in function of rugby performance. Rugby competition consists of a variety of activities, including standing, walking, running, jumping, kicking, throwing, catching, tackling, pushing, and pulling [16, 24]. These actions occur at different speeds, intensities, in different directions, and require qualities such as flexibility, speed, agility, endurance, and coordination. Quantification and comparison of the metabolic demands that are incurred is challenging, considering the multifactorial approach needed to address the inherent variability in movement within and between games, as well as the variability within and between levels, positions, and age groups [22, 24, 41, 42, 81, 98, 101, 104].

As the ball is typically in play for less than half of full game time (~29 – 45 min.), match demands can vary greatly from the "worst case scenario". This variability needs to be accounted for when preparing players for the most intense match periods [105, 106]. Of note, despite low-intensity activities accounting for about 85% of the full game time, mean heart rates (HR_{MEAN}) of 135-180 beats per minute (bpm) have been reported, with peaks to 190 bpm. In elite and international rugby players, values greater than 80% of HR_{MAX} and VO_{2MAX} are reached for most of the match time (68% - 80%), averaging 88% of $HR_{MAX.}$ [22, 107, 108]. These high work intensities are typical for rugby-specific efforts, 95% of which are less than thirty seconds of duration. Nevertheless, players accumulate total distances (TD) between 4.4 and 7.2 kilometres (km) in RU matches [22, 24, 26, 101, 107-109].

Relative distances (RD) have been recorded across RU competitions in New Zealand, ranging between 68 to 76 $m\cdot min^{-1}$, and averaging around 70 $m\cdot min^{-1}$ in overseas competitions [27, 28, 110]. These work rates account for approximately 728 to 962 m of HIRD (≥ 16 $km\cdot h^{-1}$) [110]. Because of the intermittent nature of the game, low average speeds (V_{AVG}) have been reported between 4.5 and 5.5 kilometres per hour ($km\cdot h^{-1}$). In open play these speeds can nevertheless rise to 18 to 29 $km\cdot h^{-1}$ for players involved in the action, with maximum speeds (V_{MAX}) that can exceed 30 $km\cdot h^{-1}$ for short durations [24, 105, 107]. Nevertheless, relative speed zones, in addition to absolute thresholds, further buttress that most of game distance travelled entails lower-intensity locomotion, such as walking and jogging (e.g., 84 -86% at ≤50%V_{MAX}, for forwards/back respectively) [24].

Mean work duration has been reported to be 19 seconds on the international level [105]. Most frequent work to rest ratios (W:R) range from 1:1 to 1:1.9, demonstrating rest periods are generally longer than the work efforts that precede them [22, 105]; however, work periods of up to 70 seconds have been recorded [105]. Short recovery periods of under 20 seconds nevertheless contribute to the anaerobic component in rugby [22]. Blood lactate concentrations have consequently been found between 2.8 and 6.7 $mmol\cdot L^{-1}$, with peak blood lactate concentration ranges of 5.8 to 9.8 $mmol\cdot L^{-1}$ in international RU players[22, 105].

Therefore, it seems evident that rugby players must be aerobically and anaerobically well-conditioned to deal with the activities during the full length of the match. Positional demands should also need to be accounted for, whereby backs on average perform more running at higher speeds, and forwards require more capacity for repeated accelerations and collisions [24, 106, 109-112].

In comparison to senior players, studies in RL and rugby 7s have found large discrepancies with youth match demands [101, 113-115]. In line with this, emerging evidence from RU youth play increasingly shows adolescent match demands differ from those in senior matches, warranting more research [16, 114, 116]. Furthermore, physical and kinematic match variables in RU youth also seem to vary between age cohorts and playing positions, yet not significantly on all accounts [117]. In English academy players (U16/18) and U20 internationals, TD (3.8-6.2 km) and RD (58.7-79.8 $m \cdot min^{-1}$ / 3.5-4.8 $km \cdot h^{-1}$) were found to be lower than previously mentioned for seniors [72]. Australian U14 to U18 representing various levels of play, also recorded around 3.8 km per hour of match play, on average [117]. In South-African U19 and Australian U16 and U18 distances of 4.5 and 5.8 km per game were found [118, 119]. The observed ranges in youth do however overlap with those recorded for their senior counterparts; and, as in the senior game, these measurements are dependent on playing position [72]. Furthermore, specific outcome measures do not show a uniformly linear evolution throughout the developmental pathway [16, 116]. Consequently, comparison will be a function of the specific youth cohort, the players' roles, and the considered performance measure.

Within performance measurement, speed thresholds are characterised by a lack of uniformity across the relevant body of literature, making it difficult to accurately evaluate distances in movement categories [72, 120]. Despite this challenge, Venter and colleagues found around half of total game time in U19 matches was spent walking (<20% V_{MAX}). With the inclusion of standing, nearly three-quarters of game time was accounted for [118]. Similar low-speed movement patterns (>80% of full game time) were seen by Hartwig and colleagues in 14- to 18-year-olds. Higher-intensity movements, like "jogging", "striding", and "sprinting" only accounted for roughly 19% of game time. The researchers reported a sprinting distance of 432 m at a frequency of 29 sprints, normalised per match [117]. Various metrics and thresholds are also typical for speed categories within the English developmental pathway. The second-to-highest category reported by Till and colleagues, arguably HIRD, shows distances from 138 to 1460 m and speeds of 15 to 28 $m \cdot min^{-1}$. These values are comparatively higher than the highest speed band, that ranged between 0 and 656 m. Parallel to the senior game, most distances in youth RU matches are nevertheless covered at low speeds [72].

Other performance variables that have gained popularity are proxy-measures of loading, such as Player Load™, Player Load™ 2D, and Player Load™ Slow, measures of accumulation of accelerometric data from all three axes [121] These measures have been correlated well with collision-based activities and TD in youth RU research, and with internal loading measures in professional soccer [121-123]. Based on such measures, the available data seems to indicate that, like the senior game, youth forwards experience higher impact-related loads, likely due to more collisions [72, 118, 121]. For example, Roe and colleagues showed almost certainly greater number of collisions in U18 forwards than backs (26 ± 9 vs 14 ± 6) and outlined that for forwards, all Player Load variables showed very large correlations with collisions, whereas backs' correlations were moderate to large [121]. In addition, this data showed Player Load Slow (when GPS velocity is < 0.2 $m \cdot min^{-1}$) may be the most useful metric across positions. More in-depth characterisation of RU match demands in various youth cohorts is lacking, and further expansion of this research area is therefore warranted.

As the previous data illustrates, it is not only essential to differentiate the senior from the junior game, but also to consider that the positional demands may differ, as well as across the various levels of competition. Players in the English PRO14 competition coved more TD when compared to international players, and similar trends were seen for HSRD, VHSRD, and sprint distance. Other significant differences were noted between competition levels on most measures of intensity, among which international players showed the highest levels of "high metabolic load" (i.e., explosive distance (>2 $m \cdot s^{-2}$) or HSRD (>5.5 $m \cdot s^{-1}$)), collision count, and collision load [27]. However, front and second row forwards, as well as inside backs on the amateur level, for example, have demonstrated to cover the same TD as their counterparts in higher-level New Zealand competition. In contrast, for certain positions such as outside back and back-row forwards, the increased intensity at which these distances were covered was markedly higher at the elite level [110]. In turn, in the English academy pathway, outcome measure-specific nuances were demonstrated for kinematic match demands between U16, U18, and U21, dependent on the forward or back position [16]. These differences warrant a specifically differentiated approach to player preparation rugby.

Clear uniform cross-competition differences for match-play measures cannot be established. The evidence refutes that there is a continuum of increased running demands for higher-level rugby, but various intensity-related metrics suggest that the global impact might be higher. What is clear, are the existing differences in specific performance metrics, for specific cohorts and playing positions, in specific competitions [27, 110, 124]. Therefore, position and competition level-specific considerations need to be accounted for when preparing rugby athletes for match play, interchanging competitions during the season, or when progressing to another level.

2.2.2 Injuries

Alongside the performance element in rugby, the impact of the game on its players safety has been of increasing concern. The start of professionalism saw a rise in injuries in both professionals and amateurs [32, 125, 126]. These safety concerns have been studied across various cohorts, and a trend was identified whereby the increasing demands of higher-level and senior rugby are associated with higher incidence of reported injuries [11, 15, 39, 74, 80, 125-129]. The most concerning rise in RU injuries are to the head and neck, and particularly concussions and their long-term effects on athlete health [15, 74, 125, 127, 130, 131]. As it is subject to definition and methodology [80], overall injury incidence reports range broadly across cohorts; 27 per 1000 player-hours are seen in youth rugby [74], around 47 in amateurs [76], and 81 professional senior players [128]. Extreme incidence values can be found of up to 218 per 1000 player-hours for 22 matches of the English national team's 2003 RWC campaign, when including all types of injuries [132]. These injury rates translate to a probability of between 6 to 96% for U21 rugby players to get injured during any one season, with acute muscle-tendon and joint-ligament injuries being most common [74].

The epidemiology of rugby injuries in youth shows high incidences, but varies greatly with the definition and between substrata [15, 80]. Increasing age, as well as ethnicity, incomplete recovery, training load, and tackles are amongst the identified risk factors [43, 77, 80]. Indeed, the exposure of youth to inherent components of rugby-play, the implications of restrictions thereon, and the effectiveness of education and movement control programmes have all been debated, yielding nuanced yet promising results [34-37, 71, 133]. In this sense, further longitudinal injury risk-related research with more rigid and uniform methodology is needed but restricting contact in youth rugby, such as tackling, and implementing age-appropriate training programmes, including contact techniques, can have a beneficial and protective developmental effect.

Investigation into youth players has also demonstrated that different cohorts might differ in their readiness for match-play, whereby schoolboys seem underprepared, in contrast to academy players [38]. Such discrepancies may hamper youth players' performance and put them at an increased risk of injury. Differences in position-specific demands are thereby equally evident amongst youth players, as they are at the senior level [16, 38, 117, 124]. The different types of load exposures inherent to those positions have been linked to specific acute injuries in university RU players. For example, more HIR was associated with a lower incidence of upper limb and trunk injuries, musculoskeletal, and total medical attention, whereas more impacts were associated with more time loss and medical attention for head and neck injuries. Concomitantly, weekly movement demands were higher for backs than for forwards [124].

Considering these youth-specific risk factors as well as between-youth cohort nuances, youth rugby requires a structural approach of training and match exposure to optimise players' safety, long-term development, and participation in rugby [72, 134].

In summary, comparatively high injury rates during elite senior-level matches and low rates during training (91 and 3 per 1000 player-hours, respectively), and a pooled U21 injury incidence estimate of 27 per 1000 player-hours irrespective of need for medical attention or time-loss, indicate a considerable and contextually ranging injury risk for players [74, 135]. Despite the importance of accounting for varying definitions, the injury risk for youth can be regarded higher than reported for other popular team sports such as basketball, soccer, and gridiron football (2 to 11 per 1000 player-hours) [74, 80, 128]. To that point, it seems evident and essential that player safety is kept central in match and training exposure. For this purpose, the relevant body of knowledge suggests a two-pronged approach, whereby on the one hand match regulations are adequately adapted and appropriate to specific cohorts' developmental needs. On the other hand, optimal preparation of players through a targeted and well-organised developmental approach, specific to the individual players' characteristics, is key. As factors like body mass, playing ability and performance, structural fatigue, and focus can impact players' risk of injury, it is stated that adequate levels of fitness and skill can be protective [26, 39, 136]. A well-balanced training regime that accounts for all stressors of the targeted rugby cohort is therefore essential [29, 38, 43, 137-140]. Various authors have proposed approaches for optimising readiness-to-play in rugby, such as optimising body size and composition, contact-skill training, and tactical periodisation. [23, 29, 69, 141]. Strategically managing player load by modifying collision exposure and improving fitness through increased HIRD , are practical examples that can be conducive to youth players' safety and development [124].

2.2.3 Speed categorisation

As running demands and especially HIR are of the essence in RU, one essential aspect thereof is the reporting of speed zones (V_Z), often quantified/stratified in the form of four to seven separate zones [87-89]. This practice is common in field-based sports and in research regarding movement characteristics, often but not always using labels such as "standing" and/or walking", "jogging", "striding", "cruising", "(high-intensity) running", and "(high-intensity) sprinting" [16, 100, 105, 107, 118, 142-145]. In fact, Whitehead and colleagues reported that fifty-seven percent of investigated studies regarding the football codes used variables based on V_Z [122]. Despite its use traditionally being upheld by sport scientists, reporting has been all but uniform [72, 122, 145].

Some consistency in the reporting of V_Z can be found in RU as six V_Z are prevalent [120] (Table 2); however, the arbitrary use [120, 146, 147] (e.g. pre-set 'default' GPS manufacturers' V_Z) or the unsubstantiated adoption of V_Z from other sports and research [120, 148 16, 87, 108, 149, 150] has caused significant numerical and descriptive variation within and between research in the football codes [81, 87, 88, 100, 101, 107, 108, 120, 122, 149-152]. This array of V_Z makes it very difficult to compare findings across studies and leaves the door open to potential misinterpretation of the literature [120, 147]. In turn, such misinterpretation may lead to suboptimal training practice, noting that performance evaluation based solely on rigid application of arbitrary speed thresholds has been shown to underestimate the physiological impact of demanding running activities in specific cohorts [146].

Table 2 Speed zone examples in rugby union research

Speed zones ($km \cdot h^{-1}$)	**1**	**2**	**3**	**4**	**5**	**6**
Vaz et al. (2012) 149	0-6.9	7-9.9	10-12.9	13-15.9	16-17.9	≥18
Vaz et al. (2016) 87	0-6.9	7-9.9	10-12.9	13-15.9	16-17.9	≥18
Kennett et al. (2012) 88	0-6.9	7-14.4	14.5-23	>23	/	/
Cunniffe et al. (2009) 108	0-6	6-12	12-14	14-18	18-20	>20
Hartwig et al. (2011) 117	0-1	1-7	7-12	12-21	>21	/
Read et al. (2017) 153	0-7	7-12	12-21	>21	/	/
Suárez-Arrones et al. (2012) 107	0.1-5.9	6-11.9	12-13.9	14-17.9	18-19.9	>20
Roberts et al. (2008) † 142	0-1,8	1.8-6.1	6.1-13	13-18	18-24.1	>24.1
Jones et al. (2015) 112	0-5.8	5.8-9.7	9.7-13.7	13.7-18	18-19.8	>19.8
Tee et al. (2016) 28	0-7.2	7.2-14.4	14.4-21.6	>21.6	/	/

†Derrived via video analysis as opposed to GPS

In the rugby literature, a well-founded consensus has not been put forward regarding the application of internal and external load monitoring. The lack of a 'one size fits all-approach' is to be expected considering the inherent differences in interpersonal and team sport-related characteristics, as well as the dependency on ongoing developments in GPS and microsensor technology. Nevertheless, the arbitrary nature of these V_Z should, and has been questioned [147]. GPS-derived V_Z data should be interpreted with a certain degree of caution and an appeal has been made for sport-specific V_Z consensuses, forsaking cross-sport standardisation considering the between-sport discrepancies in activity profiles [120, 154].

Several alternative approaches that have been put forward include:

- The use of absolute, individual, and squad specific V_Z based on x-amount of evenly divided velocity intervals, extrapolated from the maximal velocity reached in a representative sprint test (i.e. 5 to 10 m "flying" sprint test) [151].
- Using the second ventilatory threshold (VT_2), based on a maximal aerobic capacity treadmill test, to determine individualised or mean squad "high-intensity running" thresholds (VT_{2SPEED}) [146, 148]
- The use of three intensity zones (light, moderate and high) based on the athlete's first and second ventilatory threshold (VT_1 and VT_2) [155].
- The development of four sport-specific V_Z derived from five elite field sport velocity distributions, these being men's and woman's field hockey and soccer and Australian rules football, as well as encompassing a V_Z specific sprint definition for the inclusion of short-duration effortful lower-velocity movement [147].
- The creation of soccer-specific activity categories, as part of the football codes with overlapping movement characteristics, centred around mean velocities measured retrospectively in an intuitive re-enactment of descriptive locomotion terminology, like walking, jogging, and sprinting [156].
- The development of relative V_Z based on the percentage of individual players' game based maximum running speed (e.g., <20%, 20-50%, 51-80%, 81-95%, 96-100% V_{MAX}) [24, 118].

Rather comprehensively incorporating many of the above outlined approaches, Hunter and colleagues [157] compared the intensity distribution within time-motion analyses, using different V_Z methodologies including

1. Arbitrary zones;
2. Individualised via respiratory compensation threshold, maximal oxygen consumption (VO_{2MAX}), and maximal sprint speed (MSS);
3. Individualised via maximal aerobic speed (MAS);
4. Individualised via MSS;
5. Individualised via MAS and MSS.

While arbitrary thresholds are essential for inter and intra-player, as well as team comparison from a competitive perspective, a case is made for individualised zones in function of individual training prescription and evaluation through external load monitoring [157]. As such, it considers that locomotor category transitioning depends on individual players' performance capacity. Thus, individualised V_Z help optimise the understanding of energetic and dose-response demands in training and matches. High-speed running (HSR) and very high-speed running (VHSR) distances were found to differ up to 69% between various methods used. Consequently, Hunter and colleagues suggest allocating individual V_Z based on multiple performance markers, i.e., anaerobic threshold, MAS, and MSS [157].

2.3 Meeting rugby demands

2.3.1 General considerations

Different training and conditioning methods for improving fitness have been commonly prescribed in team sports and rugby [46, 57, 69, 86, 158, 159]. These metabolic training forms can be broadly categorised according to Stone et al., 2009 [159]:

1. **Traditional aerobic conditioning for team sports**; this is "continuous or interval-based straight line running with minimal changes in direction" (Stone et al, 2009) [159]. For example, 2-10 repetitions of 30-1000 m running intervals, every 30-60 seconds.
2. **Classic team sport conditioning**; the integration of strength, power, and speed and aerobic conditioning components in a coaching framework, aimed at the improvement of the athlete's overall functional and physical capacities in a sport specific manner [160]. For example, a basketball programme composed of typical weight training, aerobic stimuli, anaerobic stimuli, and scrimmage work.
3. **Sport-specific aerobic conditioning for team sports**; the incorporation of sport-specific skills and movements into a physical framework. For example, dribbling tracks or circuits, and SSG.

Rugby has been established as a game predominantly consisting of relatively low-speed activities, with bouts of high-intensity exercise [26, 104, 105, 161]. In terms of performance, the nature of rugby demands high amounts of endurance, speed, agility, and power [22, 24, 26, 41, 42, 81, 101, 103, 105, 106, 142]. As a result, RU has been comprehensively labelled "an intermittent contact sport exposing players to short-duration, high-intensity activities including high-speed running, sprinting, collisions, and tackling interspersed with longer periods of activity at lower intensities" [16]. Research has shown these demands can be adequately met with sport and context specific training stimuli, as optimal training benefits can be achieved when training stimuli closely match competitive demands [42, 162-165].

Cardiorespiratory endurance has been labelled an essential part of physical fitness, playing an important role in performance [166]. Rugby play is shaped through players' anaerobic capacity and thus the ability to produce energy via the glycolytic pathway, especially for the high-intensity efforts during performance-determining episodes of the game, such as scrums, tackles, and line breaks. In support, the aerobic system is continuously taxed [22, 23, 41, 42, 105, 159, 167]. Anthropometric and physiological qualities do not directly discriminate between successful and less successful rugby players but research shows a higher level of fitness and skill contributes to effective playing ability [168, 169].

The consequential increase in performance resulting from higher fitness and skill can therefore help maximise the probability of success. This rationale is an extension of the accepted notion that “an individual’s level of cardiorespiratory endurance is a reflection of the exercise intensity that can be sustained for an extended period of time”, such as a full rugby match [166]. Further to that, fitness tests incorporating speed, acceleration, and repeated work capacity measures, have demonstrated small to moderate correlations with key performance indicators (e.g. line breaks, tries scored, and meters gained) in elite rugby players [170]. This research underlines the impact of specific fitness on performance determining game components.

Furthermore, research has established that the various competitive match demands are often not met during rugby training [28, 117, 171]; these observations were also made in fourteen to eighteen year old youth players [117, 119]. Therefore, the specificity of training tasks should be thoroughly considered, and training programmes targeted to prepare players for all aspects of the game, inclusive of positional, physical, technical, and tactical elements [23, 29, 69, 138, 141]. Within this, special care should be given to the unique nature of youth-play, as school-age players require age-appropriate preparation, whereby an optimal exposure to all of the different rugby components is pursued [38, 72, 133, 134, 137, 139, 172, 173]. These considerations are an essential cornerstone to be able to optimise the efficacy of development programmes and talent identification [134, 174]. In pursuit of such programmes, various approaches have been unrolled in different countries like New Zealand, Australia, England, and South-Africa, consisting of progressive stepwise implementation of rugby competition components, considered appropriate for the respective age categories [68]. As such, these approaches ensure that talent and skills are developed systematically, so that size is not the main distinguishing characteristic, and a larger pool of players are retained. Their practical development for training practice is ongoing.

2.3.2 Practical training considerations

To effectively meet rugby demands, general training considerations must translate to practical application. In function of upholding specificity, football code-related evidence is essential. In a much cited study, Helgerud and colleagues outlined the effectiveness of a specific aerobic endurance training protocol: 4x4 minutes of incline running at 90-95% of HR_{MAX}, interspersed with three-minute jogs at 50-60% of HR_{MAX}, twice a week for eight weeks [44]. They reported improvements in soccer performance through increases in maximal oxygen uptake (VO_{2MAX}), lactate threshold (LT), running economy (i.e., gross oxygen cost of running per meter- C_R), TD covered, number of sprints, ball-involvements, and average work intensity.

These researchers also suggested that if effective conditioning could be carried out with the ball, that would be feasible in terms of player motivation, and for technical and tactical improvements [44]. Cumulatively, the body of literature does indeed provide support for the notion that game-based approaches (GBA) can positively influence affective outcomes like motivation and enjoyment, as well as physical conditioning, alongside providing technical and tactical training stimuli in team sports [47, 175, 176]. Further to that, ball games were shown to elicit high aerobic loading and improved physical fitness in eight-to-nine-year-olds, as opposed to traditional PE sessions, while rule modification in youth rugby has been shown beneficial for enjoyment and age-appropriate game-behaviours, such as successful passes and runs with the ball [173, 177].

The necessity for specific skill-inclusion is reinforced by the observation that handling a ball can come at an increased physiological cost, established to be a 1.24 $kcal\cdot min^{-1}$ mean increment, when dribbling a soccer ball, independent of the speed of motion [178]. In complement thereof, Hoff et al. (2002) investigated the effectiveness of sport-specific training in the form of a soccer dribbling track and SSG, stressing the importance of VO_{2MAX} and the anaerobic threshold as performance determinants in competition [45]. These sport-specific methods showed the potential to effectively reach threshold HR values (90-95% HR_{MAX}), which was reported to be a requisite for improving aerobic endurance. A six-week intervention carried out by Özcan et al. (2018) also demonstrated SSG to be effective at increasing the running speed at which 4 $mmol\cdot L^{-1}$ blood lactate was reached, the distance on the Yo-Yo Intermittent Recovery Level 1 test, and the number of defensive and offensive skills, while decreasing the time on the Loughborough soccer passing test, body mass, and body fat [179]. Conversely, conventional aerobic interval training only improved the blood lactate and Yo-Yo test values. These investigations into soccer players show various methods can be used to effectively physically condition players in the football codes.

A similar intermittent high-intensity nature, predominant aerobic energy requirements with close-to-anaerobic threshold HR for most of game time, and parallel movement patterns between soccer and rugby, provide plausible grounds for the transfer of effective training methods to similar team and field-based sports [22, 107, 180]. This rationale is strengthened by research investigating SSG^{RU} [87, 88, 163]. Of note, differentiation that accounts for sport and playing position-specific, and individual differences remains key. Generic methods like high-intensity interval training (HIIT) seem to match the movement demands of RU competition the most, overall, yet they lack sport-specific stimuli. Concurrently, GBT may be adequate in skill-specificity, but might not fully satisfy all positional kinematic intensity-requirements requisite for physical conditioning [28].

Nevertheless, the evidence suggests that SSG may elicit improvements in sport-specific aerobic endurance and skill in certain circumstances in field-based team sports with an intermittent high-intensity character, such as soccer and rugby [28, 97, 179]. A complementary approach, in which various training forms are strategically implemented for targeted stimuli is recommended in RU practice [28].

Inherent to team sports' competitive performance environment, are the variable demands it places on players. Training forms should therefore integrate and interlink the coordination and interaction of, and between players. As such, the nondeterministic complex social nature of team sports is taken into account; players are presented more effectively with, and consequently prepare for, the randomised situations that occur in match play [84]. Adhering to these principles of "ecological dynamics", SSG provide variability of movement actions and organisation dynamics, because of ongoing practice task-constraint manipulation [62, 84, 181, 182]. For this reason, SSG are deemed superior in team sport training compared to organism-centred approaches using part-task training and adaptive instructions in repetitive drills, as can be the case with more traditional training methods [183, 184]. These relevant models regarding GBT seem to indicate that SSG might be indispensable for integrating match-dynamics into player preparation, and therefore facilitating the application of learnt skills into a match environment, yet with a low risk of injury [95].

To further optimise the transfer between training and match performance, the frequency and duration of repeated high-intensity exercise (RHIE) ability in players, as well as sport-specific activities, should mirror those of the full game. A comprehensive review of the literature regarding the match demands of the rugby codes emphasised the importance of designing training forms that focus on these RHIE [26]. Its conclusion has been endorsed in rugby by Gabbett (2006), who reiterated that skill-specificity of SSG may offer a practically feasible in-season conditioning method for optimising team playing performance [164]. In addition, an investigation by Austin and colleagues into the repeated high-intensity nature of Super 14 RU competition matches demonstrated that training and conditioning should be inclusive of the activities typical of rugby play [161]. The metabolic demands of tackling, scrummaging, rucking, and mauling are high. Modifiable, functional, and position-specific training forms would thereby be desirable; as is the importance of competition-specific intensity intervals (i.e., worst-case scenarios, maximum output with minimum recovery) that should be implemented in training.

The current literature supports the notion that SSG are an effective and sport-specific training modality. SSG have been shown to provide adequate stimuli to illicit improvements in key physiological variables and performance determinants. Therefore, SSG are an efficient, well-endorsed, suitable, and desirable form of conditioning, as part of a well-balanced and differentiated training routine [28, 45, 84, 163, 164, 179]. Furthermore, the adaptation of playing rules in game forms may lead to a favourable, inherently motivating, youth-minded, and developmentally appropriate game-play [173].

2.4 Game-based training approaches

2.4.1 A constraints-led perspective

With the current literature supporting the use of SSG as an effective and sport-specific form of training eliciting physical, technical, tactical, and socio-affective adaptations, the intermediary mechanisms underpinning those reported benefits are grounded in scientific rationale. Based on the conceptual work of Kugler, Kelso, and Turvey (1980, 1982) regarding coordinative structures as dissipative structures, and control and coordination of naturally developing systems, Newell (1986) popularised his model of constraints [63, 185-188]. This model for studying motor development in children formalised a solution to deal with the degrees of freedom problem in human movement.

Newell suggested that coordination solutions, thus movement strategies, arise from the interaction between the organism, i.e. the individual, their environment, and the task being undertaken [189]. Considering the iterative nature of each of these factors, in turn containing a virtually indefinite combination of components, the outcome will be the resultant of a dynamically changing process, in which every change in a (sub)component may lead to a different movement strategy. This in turn has the potential to cause (un)intentional stimuli for adaption in the physical, technical, tactical, and socio-affective domains.

Newell's model of constraints was extrapolated into sport science research and evolved to form a "constraints-led" approach, in which the planned manipulation of mostly task constraints, such altering player numbers, pitch size, duration, scoring, or passing possibilities, is leveraged to obtain a specific target outcome [190, 191]. These task constraints are therefore consciously imposed onto players, with their specific individual constraints such as biological maturation factors (structural) and transient motivation (functional). When these constraints are adequately applied in a suitable training environment (e.g., temperature, humidity, and sound level), the constraint-led approach can lead to favourable outcomes, as documented in sport science.

Subsequent to that, authors such as Araújo et al. (2006) and Davids et al. (2010, 2012, 2013) have further investigated information-based performance in team sports and elaborated on decision-making and skill-acquisition with concepts such as ecological dynamics and organismic asymmetry [84, 181, 183, 192]. Furthermore, founded on the constraints-based theory, Davids and colleagues formed a wider pedagogical framework around the use of SSG in physical education [193]. In RU, Passos et al. (2008) found that decision-making needs to be optimised by applying constraint manipulation, such that stability and variability drives players to explore the playing environment for unique solutions to the problems presented [62].

2.4.2 Teaching Games for Understanding

Since its conception by Bunker and Thorpe (1982), Teaching Games for Understanding (TgfU) has evolved from a theoretical concept in the educational space to an applied model [64, 194, 195]. The presupposition was that children are more engaged in a 'tactical' model, developing skills out of appreciation for challenges faced in the environment, created through appropriately designed games. TgfU contrasts the 'technical' models, which require proficiency of isolated techniques out of context, before applying them. In TgfU, SSG are simplified versions of an official game (sport), with the same essential tactical structures, but modified in terms of player number, playing area, and equipment to match the target groups' characteristics and abilities, allowing for stepwise progressions towards mastering the game essentials [195]. The transition of this approach into practice has been reported to be moderately effective in terms of all aspects of TGfU-knowledge penetrating teachers' and coaches' practice [195-198].

These GBA have nevertheless made their way into team sport training research as an adequate method for improving tactical awareness and decision-making, (e.g. improved off-the-ball adjustments and support play in soccer players), alongside promoting socio-affective qualities (e.g. experience of greater enjoyment, game-involvement, and motivation) in competitive team sport environments [175, 176, 199]. Empirical and evidence-based indications of its effectiveness for developing physical fitness and technical skill are available; for example, improved VO_{2MAX}, repeated sprint ability, muscle power, and passing execution and accuracy have been reported. But the literature in not uniform and conflicting results exist [47, 96, 199].

Researchers have repeatedly alluded to the importance of targeting the performance environment in team sports training, which includes the coach's role, as well as design elements such as task constraints, player number, and pitch size, to ascertain beneficial outcomes with SSG [84, 175, 176]. A plethora of situational examples has been presented, among which ball possession-rule changes leading to more positional attacks and ball contacts, coach's presence decreased successful passing, increased pitch size leading to a decrease in unsuccessful dribbles, and smaller formats catering to greater playing volume and number of attacks [175].

These reviews and conceptual investigations have as such provided either contextually-bound examples and/or general conclusions, which are difficult to extrapolate broadly or apply concretely. In spite of these efforts, the dynamics between and the degree to which SSG design variables can positively affect performance qualities, as well as the methodological quality by which this is measured, are not fully understood and still debated [47-49, 96, 175, 176].

The modified 'downsized' nature of SSG make them practically and logistically useful in team sport settings. Lauded for contextualising training, and thus their potential to simultaneously enhance all performance qualities in a team sport-specific manner, the interest in SSGs has surged [47, 49, 84, 175, 176, 199]. Consequently, investigations into a range of aspects within this general research area have risen considerably, e.g., [46, 58, 61, 84, 85, 200]. In the football codes, the intensifying research has led to a soccer-centric plethora of SSG literature [46-49, 59, 96, 97, 156, 175, 201-204]. In contrast, the relationship between SSG design and performance outcomes in rugby remains relatively understudied, especially in RU [96, 97].

2.4.3 Small-sided games in rugby union

The full-sided match demands in RU are increasingly more well-established, and research using microsensor technology is continually aimed at bridging the gaps regarding cohort and context-specific methodology [26, 106, 110, 114, 122, 205]. In function of these match demands, training prescriptions have been put forward for (elite) senior RU play by authors such as Gamble (2004) and Duthie (2006) [23, 69]. A preliminary search at the commencement of this doctoral investigation (November 2018) resulted in four identified SSG training studies (Table 3) [86-89].

Initial evidence of game-based conditioning in the RU population was provided by Gamble (2004), and improvements in markers of cardiorespiratory endurance were documented using various design elements from netball, American football, and soccer, aimed at keeping players actively engaged [86]. A team of thirty-five elite-level senior RU players saw favourable evolution in $\%HR_{MAX}$ and $\%HR_{RECOVERY}$ response to a weekly intermittent multistage shuttle test, following exclusive preseason SSG exposure. No control group was present but considering the conditioning was only done through GBT, its effectiveness in this cohort stands plausible.

The influence of player number and pitch size on time-motion and acute physiological responses in a RU cohort was first investigated by Kennett et al. (2012) [88]. The authors identified the lack of knowledge regarding SSG in RU and studied 4v4, 6v6, and 8v8 touch rule formats on a small (32 x 24 m) and large (64x48m) pitch during an eight-week in-season period with semi-professional senior players. This study was simultaneously the first RU study to incorporate 1 Hz microsensor monitoring, as well as blood lactate and RPE. All time-motion variables were significantly lower for small as opposed to large pitches, including RD (94 ± 9 vs 121 ± 10 $m \cdot min^{-1}$) , HSR (88 ± 49 vs 319 ± 120 m), sprints (0.4 ± 0.7 vs 2.5 ± 2.0, and V_{PEAK} (21.3 ± 2.7 vs 25.8 ± 2.7 $km \cdot h^{-1}$). In turn, 4v4 showed higher values than 8v8 for RD (114 ± 16 vs 100 ± 16 $m \cdot min^{-1}$) , HSR (273 ± 179 vs 153 ± 115 m), and sprints (2.1 ± 2.4 vs 1.0 ± 1.2). Blood lactate and RPE were also highest in 4v4 (8.9 ± 3.2 $mmol \cdot L^{-1}$ and 17.4 ± 1.5) and on a large pitch (8.2 ± 3.4 $mmol \cdot L^{-1}$ and 15.8 ± 2.2). Overall, HR_{AVG} responses were just below 90% of HR_{MAX} and similar across player number and pitch sizes. It was consequently concluded that less players and a large pitch size elicit higher physiological and kinematic demands.

Also in senior rugby players, Vaz and colleagues (2012) monitored forty experienced (i.e., >5 years (inter)national level) vs inexperienced (i.e., ≤ 1 years) players through GPS, HR, and video recording [89]. A twelve-minute continuous 6v6 SSG format (60 x 40 m) was repeated eight times in a four-week period. Speed zone analysis (V_{Z1-6}: 0-7-10-13-16-18-≥18 $km \cdot h^{-1}$) revealed more distance was covered by experienced players in V_{Z1} (549.9 ± 55.1 vs 551.2 ± 57.6 m), V_{Z2} (186.4 ± 56.5 vs 203.5 ± 49.1 m), V_{Z3} (175.7 ± 45.3 vs 190.5 ± 60.5 m), V_{Z4} (120.9 ± 37.7 vs 124.7 ± 46.9 m), V_{Z5} (49.0 ± 25.5 vs 52.6 ± 23.3 m), and V_{Z6} (94.0 ± 73.8 vs 99.1 ± 61.1 m). However, statistical significance (p<0.001) was reported for "the single effect of partial distances" with pairwise differences in all but V_{Z2} and V_{Z3}. Of note was also that "interaction was not significant". Therefrom, it is understood that between-group differences were not significant and that across groups similar distance was covered "jogging" and "cruising" [149]. Total distances were also similar between novice and experienced players (1176.2 ± 168.6 vs 1226.9 ± 145.9 m) Both groups spent similar time in V_Z, with the time spent in each zone falling significantly (p<0.001) with rising speed. Most time was thereby spent in V_{Z1} (72-74%). A cardiorespiratory response of ≥90 % HR_{MAX} (HR_{Z4}) was achieved for two thirds of game time (~8 min) in both groups [89]. Intensity zones (HR_{Z1-4}: 0-75-85-90-100 %HR_{MAX}) were significantly different for time (p<0.001), but "no interaction with group was found". Experts and novices therefore experienced similar cardiovascular loading. Performance indicators (tries, passes, and tackles) were in favour of more experienced players. Thus, experienced players performed better in this specific SSG format, which seemed suitable for specific rugby conditioning irrespective of technical and tactical excellence.

The same research group investigated the effects of four SSG formats (1v1, 2v1, 7v7 x2) with different playing rules (Table 3) on physiological and kinematic demands in elite senior RU players [87]. Significant differences (p<0.001) were established between al V_Z, except for z2 - z3 and z5-z6. Similarly, number of impacts also showed significant differences between zones, except for z2-z4 and z5-z6. Lastly, HR_Z were significantly different, with most time (~27%) spent above 90% HR_{MAX}. These results disallowed statistical differentiation between SSG formats and furthermore, a lack of systematic experimental design and the analytical approach made it difficult/impossible to differentiate between factors that contributed to the observed differences, making it challenging to derive clear practically meaningful conclusions. Nevertheless, less players seemed to cater for less V_Z variability, and while TD was relatively equal across formats, more distance was covered in the lowest V_Z, overall. Larger formats tended to allow for higher TD in lower speed ranges when compared to the smaller format SSG. All SSG led to intensities above 90% HR_{MAX} for up to four out of fifteen minutes game time (1v1), despite low-speed running and low-intensity impacts being dominant characteristics. The authors concluded that SSG with less players and smaller pitch sizes elicited greater physiological responses and time-motion demands. This study provides evidence that SSG design influences physiological, physical, and kinematic markers. Therefore, it is logically plausible that specific formats be used to cater to specific demands.

Table 3 Rugby union SSG

Authors	Player number Format	Pitch size	Duration	Regulation
Gamble et al. (2004)	Not specified	Not specified	Several non-specified work bouts	Several rule modifications derived from gridiron, netball and soccer aimed at ensuring constant work rate
Kennett et al. (2012)	4v4 6v6 8v8	Each SSG on 32x24m (S) 64x48m (M)	2x9 mins	Modified rugby touch rules
Vaz et al. (2012)	6v6	60x40m	12 mins continuous	2011 IRB rules
Vaz et al. (2016)	a. 1v1 b. 2v1 c. 7v7 d. 7v7	a. 30x30m b. 30x30m c. 50x35m d. 100x70m	a. 15 mins b. 15 mins c. 15 mins d. 2x7 mins	a. Evasion skills b. Evasion skills c. Union rules-focus on possession/ contesting d. Sevens’ rules

In contrast to the body of knowledge regarding RU senior match, training, and SSG demands, youth RU demands have received limited attention and the intensifying research focus on this substratum has been relatively recent [16, 72, 116-119, 121, 124, 139, 206]. Unlike other team sports such as RL and soccer, senior RU data has generally served as a model to map out the characteristics for youth play [16, 23, 151, 207, 208]. Awareness regarding the necessity for a differentiating youth-specific approach is growing [38, 68, 72]. Despite the established disparities between the movement demands in senior and adolescent RU matches and their on-field training practice, the need for more representative training has not translated into SSG^{RU} focussed investigations [28, 117, 119, 139, 171].

This initial body of research surrounding SSG in the RU population has established itself slowly in the last two decades. With conditioning effects and demonstrable differentiation between formats and RU cohorts, the initial results were promising in terms of its potential for practical application. Studies are scares however, and their designs lack a focussed line of investigation. Specifically, the exact effects of SSG design variables on the specific RU population remain unclear. Senior and elite *cohorts* have been studied, but attention to youth RU players seems minimal. Cumulatively, the effectiveness of this type of conditioning for improving physical fitness and skill in youth RU players warrants further investigation.

2.5 Conclusion

This review describes the determining characteristics of small and large-sided game-play in RU. To further players' development and performance, it is important to understand the underlying mechanisms of the game in all its formats. The match demands of RU have been studied more extensively in senior than in youth players and reveal a multi-layered sport that requires specific high-intensity efforts. A multifactorial and differentiated approach, in which age, positional, and competition-specific considerations are made, seems recommended to prepare for the rigours of competition. Various methods seem to be necessary to complement each other for this purpose. Because of its reported potential to contextualise competition demands and their practical convenience, SSG seem a necessity. The relevant body of knowledge for the RU population indicates that various game-based formats could be effective at improving performance components. However, the evidence is scarce and lacks uniformity. Strong conclusion regarding the effects of design variables on kinematic, physical, or physiological parameters in youth RU players cannot be made at this time. Further research is therefore warranted and a structural approach to its design is indispensable. As such, SSG could be applied systematically to optimise players' development, and ultimately RU performance.

KEY POINTS

- **Point 1:** Rugby game-play requires sport-specific anthropometric and performance characteristics, and yields intermittent high-intensity physiological, kinematic, and physical demands that increase with rising competition-level. Variation in those match demands is evident for different competitions, positional groups, and age categories. .
- **Point 2**: Well-considered preparation of players is essential for success and SSG could play an indispensable role by providing a practically conducive training method to improve physical, tactical, technical, and socio-affective components in a sport-specific manner.
- **Point 3**: The match demands of RU seniors have been investigated and training frameworks have been proposed. However, the evidence on SSG^{RU} is scarce and lacks a focussed line of investigation for effective targeted application in practice. In addition, limited research has focussed on the game demands below the senior level. Consequently, knowledge about the application of SSG to youth seems absent.

CHAPTER 3

Developing a focussed line of investigation

Chapter prelude

Chapter 1 and Chapter 2 have established that rugby plays a global role and that the sport is characterised by specific demands which necessitate a specific and multifactorial approach. Within this approach SSG were identified as a practically useful and reportedly effective method for preparing players for the rigours of the game. So far, the bundled evidence has made it clear that the knowledge regarding SSG^{RU} *is lagging and lacks focussed line of investigation. Furthermore, this preliminary body of knowledge does not contain any information regarding youth players. In response to these observations, Chapter 3 will be aimed at developing a focussed line of investigation to systematically advance the knowledge regarding this topic in a methodologically correct and practically useful manner.*

3.1 Doctoral research design

This doctoral study consists of prospective exploratory and cross-sectional research. The exploratory component was completed in the first phase, followed by cross-sectional studies in phases two and three (Figure 4). The flow of research practice has meant that these phases overlapped. The practical, field-based components of this investigation constituted a combined (quasi-) experimental and observational design, with the following specific characteristics:

- ***(Quasi-) Experimental***: SSG, minimal external factors
- ***Observational***: Competition games
- ***Prospective***: Variables measured through direct recording in the present
- ***Cross-sectional***: Stratified group measured at (several) single point(s) in time
- ***Predictive-correlational***: Describe / predict response to variations in SSG design
- ***Cohort studies***: Male RU squads
- ***In randomised block design***: Experimental conditions applied to age groups / playing levels

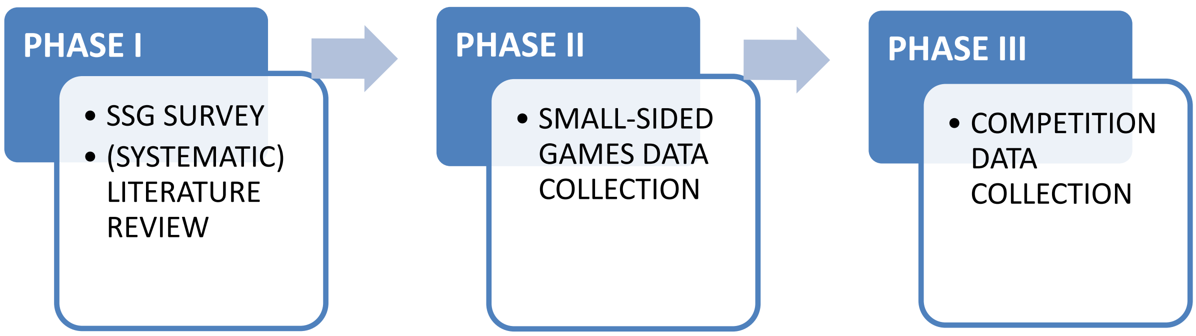

Figure 4. Doctoral study workflow

Permission for this doctoral research was obtained through the University of Waikato Human Research Committee. Approval documents HREC(Health)2019#15 and HREC(Health)2019#16 are available as Appendix 1: Ethical approval.

3.2 Study population and sampling

This doctoral investigation targeted New Zealand male youth RU players. The primary aim was to collect, collate and analyse data from the available youth strata (Figure 5). Non-probability voluntary response sampling (survey), and non-probability purposive sampling, as well as convenience (availability) sampling were used to obtain population samples.

Within the proposed population strata, the following cohorts were accessed:

- School RU under fourteens (U14)
- School RU under fifteens (U15)
- School RU under sixteens (U16)
- School RU under eighteens (U18)
- School rugby sevens (7s) U15
- School 7s U19
- International-level RU seniors

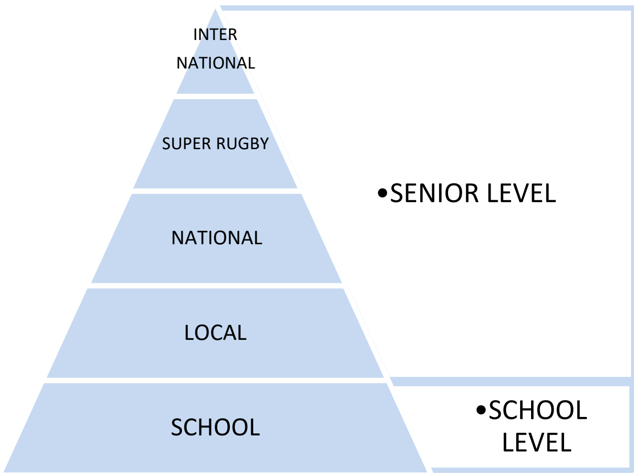

Figure 5 Levels of New Zealand rugby play

Based on the exploratory review of the relevant literature (sample size n=15-40; n_{MEAN}= 25), a secondary school RU sample of approximately thirty players or more per group was the objective for youth rugby SSG and matches [16, 56, 57, 206, 207, 209]. In line with research samples (n=14-69; n_{MEAN}=31) investigating the demands of senior rugby SSG and matches [16, 25, 86-89, 210], a target sample of approximately thirty players was also set for the competitive level. This sample selection was mainly based on proximity to the Bay of Plenty - Waikato area, and availability. Within school-level rugby, participants were randomly assigned to different formats of SSG by using a table of randomised numbers and player lists provided by teaching/coaching staff prior to the start of the data collection. Within the competitive strata, players were assigned to selected formats of SSG by the coaching staff, with no interference by the investigators.

3.3 Research questions

Primary research question:

What are the physical, physiological, and kinematic demands of relevant small and large-sided games in youth rugby union

Elementary research questions:

1. **How do practically relevant rugby union small-sided game formats alter physical, physiological, and kinematic variables?**
    a. Which SSG formats are applicable to and valuable in practice?
    b. What is the effect of player number on HR, GPS, and RPE?
    c. What is the effect of field size on HR, GPS, and RPE?
    d. What is the effect of SSG repeated bouts on HR, GPS, and RPE?

- IDENTIFICATION OF RELEVANT SSG FORMATS
    - Theory-based ➔ (Systematic) literature review
    - Practice-based ➔ Survey study

2. **How do the demands of selected game formats change for school-age male cohorts in New Zealand rugby union?**

- SSG ANALYSIS: Application and data collection of identified SSG formats in different strata:

Secondary school age groups

3. **What are the physical, physiological, and kinematic characteristics of full-sided games in school-age male cohorts of New Zealand rugby union youth competition?**

- MATCH ANALYSIS: Full game data collection and analysis for potential cohorts, as above.

3.4 Methods

The purpose of the following methods section is to provide an overarching framework of the data collection, measurements, and analysis applied to this doctoral investigation as a whole. This comprehensive preview will outline the main methods that were used recurrently throughout the practical studies, providing the reader with a preconceived understanding of the practical execution. This understanding will facilitate and expedite the interpretation of the individual studies.

3.4.1 Data collection chronology

A wide-scope survey study was developed from May 2019 and ran between August 2019 till August 2020 to obtain an evidence-based perspective on various aspects of the in-practice use of SSG in RU. In conjunction, a scoping literature review was followed up by a systematic literature review between October 2019 and September 2020, to establish a base of understanding regarding the available body of knowledge; specifically, the evidence on the use and of SSG in RU. Publication of the literature review was pursued until March 2021, when it was postponed due to circumstantial and content-related challenges. The survey studies were submitted for peer review in 2022 and 2023, as was the first SSG study.

Sampling for secondary school cohorts, local clubs, and the National Provincial Competition (NPC) 10 began in June 2019. A national list of secondary schools was obtained from the Ministry of Education. Schools were therefrom systematically contacted based on proximity to the research centre (Tauranga, Bay of Plenty, New Zealand) for logistical purposes, to determine availability of their youth rugby squads. Training and match data were collected from school-level squads and an elite-level team, competing internationally, on several pre and in-season occasions, for the period of February 2020 to April 2021.

3.4.2 Data collection procedures

The participants from youth cohort underwent several bouts of different SSG on three pitch sizes, and full matches. During these, the participants were monitored through GPS, HR, and reported their RPE to determine the effects of different formats of RU game play on acute physiological, physical, and kinematic variables.

3.4.2.1 Pretesting

Participants in this doctoral investigation were informed about the project, either through an information session held in situ by the lead investigator, or by their coaching staff, inclusive of a written document containing all necessary information and a summary version (Appendix 2: Player information sheet). Written consent was given by the participants, and where necessary also the parents or legal guardians (Appendix 3: Informed consent form). Following this, in school-level samples, anthropometrical measurements (i.e., age, body mass, stature) were collected by the lead investigator (Appendix 4: Player form). These measurements in competition-level seniors were made available by the coaching staff. If needed, the participants were familiarised with the protocols and measuring equipment (i.e., HR monitor, microsensor device and vest, RPE scale), prior to the start of testing. Baseline measurements (i.e., $HR_{MAX,}$ top speed (V_{TOP})) were established as part of the familiarisation protocol by using a 40 m straight-line maximal sprint and a rugby-specific 1200 meter shuttle run (i.e., "Bronco") [211, 212].

3.4.2.2 Testing

Prior to any testing, microsensor devices, vests, and HR devices were laid out. Microsensor units were activated in open air at least five to ten minutes before player allocation, to secure a signal (4 – 12 satellite connections). Satellite lock was checked during player allocation. If no good signal was established, the unit was restarted to re-establish connection. Data quality was also visually assessed during data processing. RPE was collected by research staff and assistants on a written form. After data collection sessions all equipment was collected and data was subsequently downloaded using the manufacturer's software.

Full games

Official RU full fifteen-a-side and seven-a-side matches were monitored at school level in consultation with teaching/coaching staff. There was no interference with game day protocol, the line-up, team strategy, or coaching. Official RU playing rules were applied and an official referee lead the game.

Small-sided games

Based on previous research [44, 45], the participants executed three four-minute bouts of several SSG on different pitch sizes, interspersed with four-minute active rest intervals. During rest intervals participants were instructed and reminded to swiftly communicate RPE values and lightly jog till the start of their next SSG bout.

The participants were allowed to drink water ad libitum. On the school-level, coaching staff were asked not to provide feedback nor encouragement.

Adapted RU touch rules were applied to minimise the risk of injury inherent to tackling, and to maximise the conditioning effects through running demands. The aim of each of the SSG was to accumulate as many points as possible through scoring tries. After a try was scored, the ball was turned over to the opposing side and the game was immediately resumed from the try line. Each attacking team received five plays (touches). A touch was made when the ball carrier was tagged by a defending team member with both hands. Forward passing was not allowed.

Following a touch, the ball carrier had to place the ball down between their legs and the defending team quickly retreated five meters (~5 steps) to set up their defensive line. The following play was immediately instigated by the attacking team member through picking up the ball and passing to a team member. After five touches the ball was turned over to the opposing team by placing the ball down. The game was then immediately resumed when the opposing team executed their first pass.

No conversions or penalties were awarded, and no lineouts were carried out. If a foul was made, the ball was turned over to the opposing team and the game was resumed immediately at that position. When the ball went out of play, it was turned over to the opposing team and the game was resumed immediately at the side-line with a pass. Numerous balls were available around the pitch area to ensure continuous game play.

Considering the general lack of consistency regarding design variables demonstrated in the SSG literature, and the aim of this doctoral thesis to impose a base structure in SSG^{RU}, the formats and pitch areas were informed by the systematic literature review and survey studies (Phase 1), to be kept representative to the area available in a full game (Figure 6; 70x100 m) and best-practice SSG training. The selection of SSG were consequently established to be: 3v3, 5v5, and 7v7, with pitch sizes defined as follows:

- **Small (S)**: $^1/_8$ of the full rugby pitch (25 x 35 m)
- **Medium (M)**: $^1/_4$ of the full rugby pitch (35 x 50 m)
- **Large (L)**: $^1/_2$ of the full rugby pitch (50 x 70 m)

.

These formats also have the following rationale:

- Paired teams reflect the full game,
- A gradual linear rise in player number and pitch size, optimising the opportunity for the detection of changes in the variables studied, and potentially further extrapolation,
- Keeping optimal player activation through interaction (i.e., passing and receiving opportunities) central,
- Considers practical training logistics (pitch area/player number) and easy organisation, thus facilitating carry over to RU training practice.

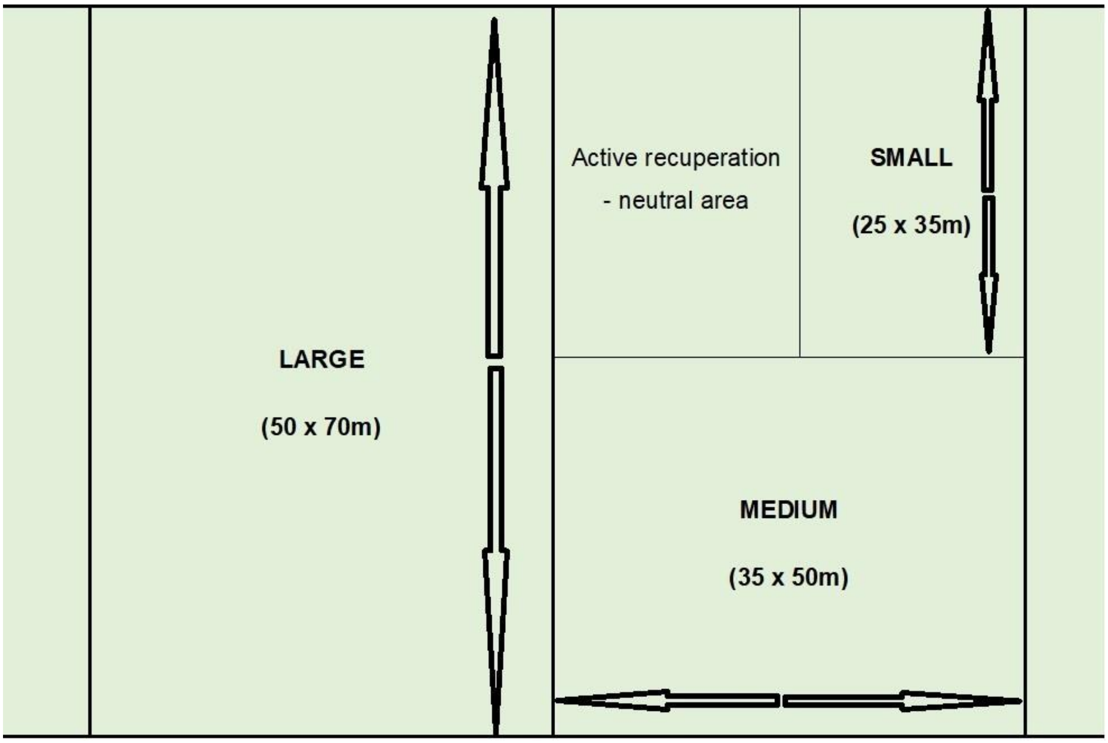

Figure 6. Division of the rugby pitch - SSG playing area

The format of testing for the SSG was planned within several data collection events to be (pseudo-) randomised. However, data collection was subject to availability and time constraints of the study samples, so that the application of the SSG was adapted to necessary logistical considerations.

3.5 Measurements

Portable and integrated microsensor technology, combining GPS, HR, and triaxial gyroscope and accelerometery, has increasingly been used for sport purposes since the turn of the century [120, 213]. Through a partnership with VX SPORT™, similar technology was used in this doctoral study to record physical, physiological and kinematic data; i.e., VXWR5Lb units containing 10 Hz GPS (Glonass, QZSS, SBAS, Galileo & BeiDou compatible), tri-axial 100 Hz accelerometer, 18 Hz magnetometer, 18 Hz gyroscope, and coupled Suunto HR sensors, with compatible manufacture's software (VX View version 5.4.3.53). The GPS and compatible HR units were worn in a purpose-built VX vest, with integrated chest electrodes, that places the units between both scapulae for optimal safety and player movement. These types of devices, including VX SPORT™, individually and combined, have been used extensively for research purposes in sport [214-216]. Especially in the football codes [120, 217], including rugby union [16, 28, 86-89, 108, 112, 118, 171], RL [56, 101, 209, 218, 219], 7s [115, 146, 220], and soccer [48, 123, 151, 208], they are prevalent in research regarding similar conditions and contexts to those in this doctoral investigation. Additional complementary measurements included RPE and injury occurrence. An overview of the measurement tools is available in Table 4, and an individual assessment of the study measurements will be discussed next.

3.5.1 Speed testing

To categorise running speed into relative units (%V_{TOP}), players' top running speeds (V_{TOP}) were assessed through a 40 m straight-line maximal sprint test as part of the familiarisation process with the microsensor devices, following an appropriate warmup [212]. Top speed in sprinters can be observed after 70-80 m [221, 222]. However, this test keeps best practice in mind (cf. 10 - 40 m sprint testing [23, 92]), emphasises acceleration over maximal speed [23, 223], and therefore ensures the highest possible rugby-specific running speed is reached considering the game characteristics [22-24, 26, 81, 108, 142, 224] and inherent rugby field properties. Importantly, it is also easy to reproduce in training practice (i.e., circa length of a half rugby pitch). The 10 Hz GPS device used (Table 4) ensures valid measurements in this specific unidirectional straight-line running context [120, 217, 225]. Being deemed a valid and reliable alternative to timing lights runs over 30 meters, GPS monitoring allowed for a more optimal field-based group approach [225-227].

3.5.2 Maximal aerobic power testing

A rugby-specific 1200 meter shuttle run, i.e. “Bronco fitness test”, was used to test participants’ HR_{MAX} [211]. This test followed the speed test after a recovery period of minimally fifteen minutes, using the same microsensor technology. Shuttle run testing, including the Bronco, has been demonstrated valid and reliable across a range of different populations [211, 228-233]. The test consists of five consecutive 20-40-60-metre there-and-back shuttle runs, performed continuously. As opposed to laboratory-based graded maximal exercise protocols, the Bronco test was chosen for its rugby-specificity, simplicity, and its logistical benefits, including field-based group execution and time efficiency [233]. In instances where players did not perform the Bronco test as part of baseline testing, HR_{MAX} was attained from strength and conditioning staff or calculated from, a theoretical age-specific HR_{MAX} (208 – 0.7 x age) [234].

3.5.3 Heart rate

The use of HR monitoring as an indicator of physiological loading relies on its relationship with power output, and therefore oxygen uptake. Despite an error margin of up to 20% in estimating VO_{2MAX}, it can be used to estimate energy expenditure in group and field conditions [215, 235-237]. Accuracy and reliability of HR measurements have improved drastically over the decades it has been used in different fields, including medicine and sports. HR measurements can be influenced by various internal as well as external factors, but portable chest-worn electrode HR monitoring is considered a reliable and valid method [214, 215, 238]. A certain lag does need to be accounted for, due to HR inertia when compared to kinematic measurements [215, 239]. Research that uses HR monitoring for investigating SSG has an extensive body of literature [48, 87, 89, 209, 218].

3.5.4 Global positioning satellite system

Current technological advances and applications in sport science have led to the availability of GPS units for the evaluation of training and matches [120, 122, 240]. The use of measuring equipment and output variables can be driven by trends and should not be indiscriminate, or without targeted consideration of contextual and methodological factors [214, 217, 241, 242]. As the measurement of kinematic variables provided a considerable part of the evidence in this investigation, an adequate perspective is required on the factors that can influence these outcome variables obtained from GPS measurements. In this manner the data can be framed within the most appropriate context, and consequently, its meaning can be interpreted adequately.

Several studies have labelled microsensor technology integrating accelerometers, gyroscopes, and GPS tracking at various sampling frequencies as being practically useful for the quantification of team sport performance demands [212, 226, 227, 243-248]. These studies most often investigate a specific aspect (e.g., accuracy, reliability, validity) of one or more units of a type of microsensor device, with specific characteristics (e.g., sampling frequency), using a specific test protocol; the utility for tracking movement patterns is generally studied using circuits which incorporate steady state running, acceleration, change of direction (COD), and high-speed running [243, 245, 247-249]. These specificities make broad extrapolation unfeasible, but the implications of such extrapolation are generally understated in subsequent team sport research using microsensor devices.

With regards to GPS tracking, different sampling rates are often compared to each other, or to a criterion. There is a tendency to report superior validity and reliability when comparing higher to lower sampling rates [154, 245, 246, 248, 250]. Those conclusions are however not exclusive [243]. Better accuracy is generally observed with higher frequencies, for fundamental measures of movement demands like total distance (TD), average speed (V_{AVG}), peak speed (V_{PEAK}), and speed zones (V_{Z}), in intermittent high-intensity interval team sport contexts. This superiority is especially the case for straight line efforts, and with increasing distance or duration [212, 243, 244, 247, 248, 251, 252]. Nevertheless, the evidence is not uniform, as exemplified by the findings of Johnston and colleagues that TD and peak speed showed discrepancies between 5 Hz and 10 Hz sampling frequency devices, in contrast to what is generally found for those and similar movement demands [245].

Nuance is required, as accuracy, and therefore validity, inter and intra-unit, or test-retest reliability can widely vary between and within devices and sampling frequencies. This variance occurs in both directions, depending on the outcome measure, experimental set-up, and microsensor device [227, 248, 249, 253-255]. Limitations due to diminishing accuracy are stated in function of increasing movement complexity, irrespective of sampling frequency. Various degrees of over and underestimation occur during shorter distance efforts, accelerations, COD, and very high-intensity speeds (>20 $km \cdot h^{-1}$) [154, 243, 245, 246, 248, 252, 255].

Though benchmarks of validity and reliability are arbitrary, some are interpreted as acceptable [253, 256]. Small errors (<5%) have been reported in distance and/or speed measures for team sport-specific activities, using 1, 5, and 10, Hz GPS units. The added value of higher sampling rates is ambiguous [243, 253-255]. Notwithstanding, a direct comparison of devices or sampling rates is counter-advised [252, 253, 255, 257].

It is important to note that validity and reliability of a microsensor device are a product of

1. The specific type of validity and reliability, and its measurement and error tolerance (<10%),
2. The kinematic outcome measurement that is being considered,
3. The devices' technical specifications, including, but not limited to sampling frequency,
4. The exact context in which the device was tested, and in which it is used.

Validity and reliability measures should therefore be seen on a gradual scale, handled on a case-by-case, and outcome measurement-specific basis. A microsensor device's sensitivity provides for a range of complexity in which it can be useful. A generalising consensus is growing towards an optimum of 10 Hz GPS devices, accounting for most extremes and complexities inherent to team sports with intermittent high-intensity short-duration multidirectional movement profiles [253, 255, 256]. Local Positioning Systems (LPG) show alternative potential, but further research is needed [254, 258]

To conclude, the accuracy of GPS microsensor technology has been demonstrated for human locomotion [213, 225, 259]. There are some reservations towards short-duration physical efforts and changes in direction and velocity [120, 154, 260]. Notwithstanding these data, mounting evidence of good reliability and acceptable validity with increasing sampling frequency >5 Hz for team sports with intermittent high-intensity and short-duration multidirectional repeated sprint profiles is available [48, 120, 154, 213-215, 217, 227, 238, 251, 252, 257, 260, 261]. Specifically, a systematic review of the evidence indicates that 10 Hz devices are likely to be the most appropriate for application in team sports like rugby [120, 256].

3.5.5 Rating of perceived exertion

Rating of perceived exertion was communicated verbally and noted manually (Appendix 5: Testing form). Quantifying perception of internal loading through RPE is a widely spread practice in sport research [43, 214, 261]. This use of the Borg scale during or post exercise is generally considered validated, based on existing correlations with HR, % VO_{2MAX}, and other physiological measures [43, 214, 261-264]. Some reservations can be made regarding short duration high-intensity exercise in a competitive team sport environment, like rugby, as RPE can be influenced by extraneous factors, such as the age groups (i.e., children and adolescents), exertion modality (e.g., walking vs running), and peer-influence [264-266]. The relationship between RPE and HR in isolation has thereby not been consistently demonstrated sufficiently strong[263, 264, 267]. However, Borg outlined that discrepancies can be expected and that these are to be taken into consideration when prescribing exercise [264].

Forms of RPE and HR monitoring have consequently been used to monitor global internal exercise loads, e.g., in youth soccer matches and SSG [262, 268, 269]. In practice, RPE is deemed an accessible and valuable tool, especially when combined with other intensity measures like HR, blood lactate, and % VO_{2MAX}, which strengthens its validity [43, 261, 262, 269]. Considering there is no one single definitive marker to get a complete view on total loading during exercise, a combination of internal-load and external-load measurements is most optimal [43, 218, 261-264, 267-269]. Of note, RPE has been endorsed as a valuable training load measure in rugby [138].

3.5.6 Injury

In conjunction with notation of RPE values, players were asked to report the occurrence of injuries at the end of each of the three bouts that comprised the SSG. Considering the lack of consistency and ambiguous use of the terminology in the literature, the consensus definition as given by Fuller et al. (2007) was adopted [11, 79, 80]:

*"**Any physical complaint** which was caused by a transfer of energy that exceeded the body's ability to **maintain** its **structural and/or functional integrity** that was sustained by a player during a rugby match or rugby training, **irrespective of the need for medical attention or time-loss** from rugby activities. An injury that results in a player receiving medical attention is referred to as a 'medical-attention' injury and an injury that results in a player being unable to take a full part in future rugby training or match play as a 'time-loss' injury."*[79]

For this study, a more practice-minded working definition-translation was used and communicated to the participants, whereby an injury is "**any change** that occurs during the matches or games, that is **to any degree worrisome** to the player or staff from a logical and **common-sense** perspective". In those cases, the player could take himself out of play, or be taken out of play, regardless of the potential capacity to continue or the need for medical treatment. This removal was implemented so as not to further endanger the safety or health of the player. Examples of this are, but were not limited to: sprains, muscle pain, dislocations, bleeding, concussion symptoms, serious bruises, fractures, etc. Events that could be ignored were minor scrapes and bruises, light short-term localised bleeding, and a small amount of short-term pain or discomfort, if perceived by the player as normal in rugby activities.

Table 4 Overview of study measurements

Measurement	Unit	Apparatus
Physical		
Age	Numerical	Player form – personal information
Stature	Centimetres (cm)	Seca stadiometer (gmbh & co, Hamburg, Germany)
Weight	Kilogram (kg)	Seca digital weighing scale (gmbh & co, Hamburg, Germany)
Injury incidence	Numerical and descriptive	Testing form - injury count
Physiological		
Heart Rate (HR)	Beats per minute (bpm)	HR monitor (Suunto - VX SPORT™) integrated) [270, 271]
% HR_{MAX}	%	HR monitor (Suunto - VX SPORT™) integrated)
RPE	Arbitrary units (AU)	Testing form –Borg scale (RPE^{6-20})
Kinematical		
Speed (V)	Kilometres per hour ($Km \cdot h^{-1}$)	10 Hz GPS microsensor technology (VX SPORT™)[271]
%V_{MAX}	%	10 Hz GPS microsensor technology (VX SPORT™)
Acceleration	$m \cdot s^{-2}$	10 Hz GPS microsensor technology (VX SPORT™)
Distance (D)	Meters (m)	10 Hz GPS microsensor technology (VX SPORT™)
Impacts	Numerical	10 Hz GPS microsensor technology (VX SPORT™)
Activity Load (AL)	Arbitrary units (AU)	10 Hz GPS microsensor technology (VX SPORT™)

3.6 Data analysis

3.6.1 Data selection and processing

Following every data collection session, the microsensor data was downloaded using the manufacture's software (VX View version 5.4.3.53). Individual players' kinematic and physiological data was visually assessed and manually trimmed to solely include actual playing time. Kinematic and HR data files that were identified as corrupted (technical malfunction or misuse) through numerical and graphical assessment, were excluded from further analysis. Individual data files were coded for type (SSG, bout 1, bout 2, bout 3, match half 1, match half 2) and playing minutes. Only data of actual playing time was statistically analysed.

Various inclusion methods have been applied to football code research with regard to substitutes' data [24, 148]. In this doctoral research, the number of full matches that were studied, as well as the role of playing duration on fatigue and performance, and the effect of substitutions were considered [272, 273]. Consequently, substitutes' match data was handled differently depending on the specific format. Only data files including playing bouts larger than the team's average playing duration were included for analysis of RU matches, to be consistent with prior research in RU [16, 24]. Considering limited seven-minute playing bouts were registered in the 7s matches, data files shorter than a quarter of a game (< four minutes) were excluded from further analysis to retain higher statistical power, in the awareness that this adjustment had the potential to overestimate movement variables [115, 274]. No substitutions were allowed for SSG play.

Variable and metric selection was guided by the microsensor technology software options, and informed by commonly used outcome variables in rugby, to connect with prior SSG^{RU} research (e.g., Vaz et al., 2016 [87]), and to obtain absolute benchmark targets in terms of competition demands. This benchmarking was in addition to the relative measurements, resulting in a more comprehensive perspective, as discussed in 2.2.3 Speed categorisation. Thus, specific variables and categories were reported as relative to individual players' maximal values [93, 122, 275, 276].

Top speed (V_{TOP}) and HR_{MAX} were based on the highest absolute recordings during baseline testing or matches, whereas maximal speed (V_{MAX}) refers to the highest speed performed during games. High-intensity running (HIR) category labels were adopted from the available software options and set to converge with benchmarks put forward in systematic research [93]; high-intensity running distance (HIRD >18 $km\cdot h^{-1}$), high-speed running distance (HSRD >20 $km\cdot h^{-1}$), and very high-speed running distance (VHSRD >25 $km\cdot h^{-1}$).

High-intensity acceleration (HIacc) and deceleration (HIdec) thresholds were kept to the manufacturers setting of 3 m·s^{-2}, based on prior research [115]. Relative velocity zones (V_Z) provide a more appropriate perspective on youth and lower-level play [277]. The V_Z were defined as <20% (z1), 20-50% (z2), 51-80% (z3), 81-95% (z4), 96-100% (z5) of V_{TOP} [24, 118, 278]. Relative HR zones (HR_Z) were adapted from Higham et al. (2016), based on Edwards (1993) to be <59% (z1), 60–69% (z2), 70–79% (z3), 80–89% (z4), and ≥90% (z5) HR_{MAX} [275, 279]. Further explanations regarding metrics-terminology and definition are available in the VX Sport metrics glossary [280]. The data obtained from the measurements was used to describe the player samples. Statistical analysis was performed using SPSS (version 25) and Microsoft Excel software (Excel 2016, "data analysis toolpak").

3.6.2 Descriptive statistics

All descriptive statistics were reported as measures of central tendency and measures of variability, i.e., the range and/or mean and standard deviation (mean ± SD). In addition, some descriptive results were reported as a percentage of a cohort or subpopulation. The base measurements to which this applies are listed in Table 5.

3.6.3 Inferential statistics

Inferential statistics were applied to the collected data, to draw conclusions about the population of RU players. Significant relationships between relevant qualitative variables in categorical data obtained in Phase I (Figure 4), were investigated using Chi-square (χ^2). The quantitative data that were considered in the different game formats investigated are listed as outcome variables of interest in Table 5.

Table 5 Dependent variables

PHYSICAL	1	(Relative) injury incidence ($game^{-1}$; min^{-1}; h^{-1})
PHYSIOLOGICAL	2	Average heart rate (HR_{AVG}) (% HR_{MAX})
	3	Maximal heart rate (HR_{MAX}) (% HR_{MAX})
	4	Time in five heart rate zones (HR_Z) (mins / % game)
	5	Rating of perceived exertion (RPE)
KINEMATIC	6	Average speed (V_{AVG}) ($km \cdot h^{-1}$)
	7	Maximal speed (V_{MAX}) ($km \cdot h^{-1}$)
	8	High-intensity running distance (HIRD) (m)
	9	High-speed running distance (HSRD) (m)
	10	Very high-speed running distance (VHSRD) (m)
	11	Sprints rate ($game^{-1}$/min^{-1})
	12	High-intensity acceleration/deceleration (HIacc/HIdec) ($m \cdot s^{-2}$)
	13	Total distance (TD) (m)
	14	Relative distance (RD) ($m \cdot min^{-1}$)
	15	Distance covered in five speed zones (V_Z) (m)
	16	Impact rate (IR) ($impacts \cdot min^{-1}$)
	17	ActivityLoad 3D rate (AL_{3D})
	18	Distance in relative speed zones (V_Z) (m)

Data obtained from the SSG and match play was analysed using the inferential statistical technique procedures, as described hereafter. Normality of the distribution was determined by implementing Shapiro-Wilk normality test. A Levene's test for Equality of Variance confirmed the data's homogeneity of variance. If alternatively, these conditions were not met, a non-parametric technique was considered for analysis (i.e., Kruskal-Wallis test).

The effects of the qualitative or independent variables on selected quantitative or dependent variables were investigated within and between groups (age cohorts at school-level). Multivariate and Univariate Analysis of Variance procedures (two, three, and four-way MANOVA and two, and three-way ANOVA) were used entailing:

- The effects of **FOUR INDEPENDENT VARIABLES** (player number- pitch size- age category- playing bout), or 'between-subject factors', with their respective levels (Table 6)
- On **EIGHTTEEN DEPENDENT VARIABLES and derivatives**, or 'measures', as listed in Table 5.

Table 6 Overview of independent variables for SSG formats

		Factors (independent variables)			
		AGE CATEGORY	PLAYER NUMBER	PITCH SIZE	PLAYING BOUT
Levels	1	U14	3 v 3	S	1
	2	U15	5 v 5	M	2
	3	U16	7 v 7	L	3
	4	U18/19			

Firstly, the factors' **main effects** demonstrated whether each individual independent variable had an influence on either the combined or individual outcome variables. Following, the factors' **interaction effects** showed whether specific combinations of factors (i.e., player number, pitch size, age category, and playing bout) influenced the outcome variables of interest.

Mean values for the effects were reported as outlined above (3.6.2 Descriptive statistics). The effects were interpreted through F-value and accompanying significance that was set at 5% ($p \leq 0.05$). Continued analysis for further differentiation was done through Scheffé post-hoc test, and Bonferroni correction was applied [281]. In addition, Cohen's *d* effect size (ES) using the pooled SD and 95% confidence intervals (95% CI) were selectively calculated to provide a complementary measure of magnitude.

In summary, the statistical procedures were conducted to differentiate nine individual SSG formats, consisting of three playing bouts, in four individual age categories (Table 7). In addition to this, calculations were made for pooled age groups, to establish the relevance of differentiation within the adolescent RU strata, as the body of evidence has demonstrated pooling of various age categories [117, 282, 283]. The effect of these independent variable combinations on each of the stated outcome variables of interest (Table 5) was thereby examined.

Table 7 Different small-sided game formats

Youth (U14-U15-U16-U18)														
BOUT 1		PITCH SIZE			BOUT 2		PITCH SIZE			BOUT 3		PITCH SIZE		
		S	M	L			S	M	L			S	M	L
Player number	3	GF 1	GF 2	GF 3	Player number	3	GF 1	GF 2	GF 3	Player number	3	GF 1	GF 2	GF 3
	5	GF 4	GF 5	GF 6		5	GF 4	GF 5	GF 6		5	GF 4	GF 5	GF 6
	7	GF 7	GF 8	GF 9		7	GF 7	GF 8	GF 9		7	GF 7	GF 8	GF 9

GF= Game format; S= small; M= medium; L= large

For youth 7s matches, differences within and between groups were calculated using independent sample T-test and single factor ANOVA. Heterogeneity was checked through F-test. Statistical significance was set at $p \leq 0.05$. For multiple pairwise comparisons Bonferroni correction was applied [281]. Standardised mean changes were also calculated as Cohen's ES, using the pooled SD, to indicate trivial (<0.2), small (0.2 – 0.59), moderate (0.6 – 1.19), large (1.2 – 1.99), very large (2.0 –3.99), and extremely large (≥4.0) magnitudes of difference [284, 285].

Fifteen-a-side match data collected for school-level players was analysed separately to the SSG. Each match play data set was initially checked for outliners, normality of the distribution, and homogeneity of variance, in line with that of the SSG. If alternatively, these conditions were not met, a non-parametric technique was used for further analysis (i.e., Friedman test).

Match data was analysed for descriptive statistics of the outcome variables of interest (Table 5) and complemented by the interpretation of differences in 'playing position' using a significance of $p \leq 0.05$, as well as stating magnitude of the effect through Cohen's ES.

The results of the SSG and match analyses served to inform the suitability of each of the nine game formats highlighted in Table 7 to replicate/simulate match demands. In turn, the body of evidence helps build the framework in which SSG can be utilised to optimise rugby development and performance, and thus exercise prescription across playing levels.

SECTION II

RESEARCH STUDIES

CHAPTER 4

A systematic literature review of small-sided games in rugby union

Chapter prelude

In section I, the impact of rugby in history and society, and the importance of SSG within the sport of rugby for its potential to prepare players for the rigours of the game are discussed. Following this, we identified the relevant body of research was lagging and a focussed line of investigation towards SSG^{RU} play in youth is warranted. In execution of this focused line of investigation, Chapter 4 will proceed with a systematic investigation of the subject matter, to obtain an in-depth and objective insight into the available evidence on SSG^{RU}.

4.1 Introduction

4.1.1 Rationale

Small-sided games are modified versions of a full game, to which certain design variables were altered to obtain a desired training outcome. These training forms are furthermore known as skilled-based (conditioning) games and game-based training. Following the conception of Bunker and Thorpe's "Teaching Games for Understanding (TGfU)"- model, SSG have known a surge in popularity [64]. Both prescription and investigation of SSG within team sports and generically have risen since the turn of the twenty-first century [46, 47, 50, 51, 53, 54, 58, 61, 286-290]. Most of this research has been conducted in the football codes, mainly focussing on soccer [45, 55, 57, 82, 150, 156, 175, 275, 291-296].

The resulting evidence has led to the appreciation of SSG as a useful sport-specific training method, through potential physiological, technical, and tactical benefits [45, 48, 61, 82-85, 156, 175, 201, 297, 298]. In addition, personal, social and positive affective effects have been quoted [176]. Growing consensus is being reached about its potential to concomitantly improve those inter and intra-personal qualities [175, 176]. Heterogeneity and inconsistency across SSG studies, specifically concerning design variables, has also become evident. The lack of consistency and systematic approach, together with the relative infancy of the research at this stage, limits the ability to draw definitive conclusions [46, 48, 49, 59, 60, 175, 176, 201, 204, 299].

Moreover, the available rugby-specific SSG evidence predominantly discusses rugby league (RL) [42, 56, 57, 95]. Rugby union small-sided games (SSG^{RU}) literature has been reported to be scarce [87]. Investigations into the demands of rugby are increasingly showing the necessity for specificity and differentiation [16, 22-24, 26, 81, 92, 100, 108, 116, 130, 146, 171, 206, 274, 275, 300]. Further to that, at the time of this review's initial search, (15/10/2019), detail regarding the application of SSG to various RU-populations was lacking. In recent years, structural evidence has emerged regarding the rugby codes, confirming our rationale [97]. Given the known cohort-related differences in game demands, the potential benefits of SSG training, and its perceived scarcity in the RU literature, especially for youth, as highlighted in prior sections, detailed examination of SSG in the RU population is warranted.

4.1.2 Objectives

The aim of this study was to systematically review, describe, and critically appraise the available SSG^{RU} literature and provide insight on the application of SSG to RU subpopulations.

- ***P****opulation*: Male RU players.
- ***I****ntervention*: Studies investigating SSG in RU.
- ***C****omparison*: What is the individual and overall quality of these studies, and to what degree are they at risk of bias (RoB)?
- ***O****utcome*: What are the specific measurements used, and to what conclusions do they lead individually and cumulatively?
- ***S****tudy type*: What are the study characteristics of SSG^{RU} research?

4.2 Methods

4.2.1 Protocol and registration

An initial scoping study consisting of a generic exploratory search was conducted to obtain an overview of the available publications regarding SSG in RU. Therefrom, key terminology was identified. In keeping with the spirit of the Consolidated Standards of Reporting Trials (CONSORT) statement, supported and adopted by reputable journals like BMJ, JAMA, and Lancet, conscious effort was put toward ensuring completeness, traceability, transparency, and clarity in this systematic literature review [301-303]. In aim of upholding the highest reporting standards, we explicitly adhered to the preferred reporting items for systematic reviews and meta-analyses (PRISMA); the search and selection of incorporated publications were based on the PRISMA flowchart (Figure 7) and the manuscript's format intentionally covers the 27 PRISMA checklist items, as described in the PRISMA statement [304]. The study protocol was not registered with the International Prospective Register of Systematic Reviews (PROSPERO), as systematic reviews assessing sports performance as an outcome are not accepted [305].

4.2.2 Eligibility criteria

Studies were included in the review if they met the following criteria, in consecutive order:

1. Full text available in English language
2. Academic relevance (peer-reviewed journal published, identified search terms)
3. Specific to male RU population
4. Investigation of SSG
5. Incorporation of physiologic, kinematic, or physical outcome measures
6. Inclusion and report of the effects of SSG design variables

These eligibility criteria were re-evaluated during the study selection process (4.2.5 Study selection). Criteria 6 was revoked for the initial search to allow for a larger number of studies to be included, and an exception was made for criteria 3 (female participants) during the follow-up search for one study [283], considering the meaningful contribution this study would make through its well-structured execution, relevant to the objectives of this systematic literature review.

4.2.3 Information sources

Six electronic databases were searched on 15/10/2019 and repeated on 16/06/2023. No publication date restrictions were applied. Two publications were added to the search results later that year through an alternative source, i.e., emails from a colleague and co-author. Contact was had via email with Prof. Dr. Vaz [87, 89, 306] and Prof. Dr. Coutts [88], for clarification regarding their publications. Furthermore, methodological advice was sought from Prof. Dr. Sterne [307] about RoB. Dr. Hartwig [117] was consulted on quantification of training load.

Table 8 Identification process

Databases 15/10/2019 (16/06/2023)	Search string results			Records identified	Records after duplicates removed	
	1	2	3			
Pubmed	2 (6)	0 (0)	1 (1)	3 (7)	-	(7)
Sportdiscus	6 (10)	0 (1)	1 (3)	7 (14)	-	(12)
Scopus	4 (10)	3 (4)	38 (51)	45 (65)	-	(57)
Web of Science	12 (NA)	5 (NA)	55 (NA)	72 (NA)	-	(NA)
Cochrane Library	0 (0)	0 (0)	3 (3)	3 (3)	-	(3)
Google Scholar	3 (7)	0 (0)	0 (0)	3 (7)	-	(7)
All Databases	27 (+19)	8 (+3)	98 (+27)	133 (96)	84	(64)

NA: Not available

4.2.4 Search

Based on the prospective scoping study, the following relevant search terms were identified:

1. Rugby union
2. Small-sided games
3. Small-sided conditioning games
4. Conditioning games

Using these search terms, three different search strings were composed:

1. Rugby union AND small sided games
2. Rugby union AND small sided conditioning games
3. Rugby union AND conditioning games

Following the initial scoping study, the selected search strings were individually and independently run through each of the six electronic databases, on 15/10/2019. The search strings were entered into the “article”, “title”, “abstract”, and “keywords”- boxes, as and if available, but not the “full text”. No other limitations were put in place. Different numbers of records were identified between the selected electronic databases (Table 8).

In addition, the reference lists of eligible publications were searched for additional articles. For consolidation of this thesis, the search was renewed on 16/06/2023. The additional eligible search results were integrated as a summary additional analysis (4.2.12) and used to complement and contrast the initial results in the discussion.

4.2.5 Study selection

The selection process was guided by the PRISMA flow diagram (Figure 7) using the eligibility criteria determined. Every record was imported into an Endnote software folder. Duplicates were manually removed. Individual publication titles were screened one by one. Abstracts were consulted where definitive clarity was lacking. The resulting publications were placed into a second Endnote folder, safeguarding the initial search results. Remaining publications' abstracts and article bodies were then searched for the eligibility criteria. A third folder was created, holding the resulting study inclusions (Figure 7). Two publications were obtained post-database search, through alternative channels. The iterative nature of systematic reviews was allowed for, throughout [304, 308].

4.2.6 Data collection process

All data were initially sought and extracted from original peer reviewed publications in electronic formats. Where necessary, contact was sought with the lead author for additional information. Four authors were contacted, of whom two were related to SSG study content and two for methodology-related reasons. All authors provided a response. General characteristics were extracted per study (Table 9).

4.2.7 Data items

Data was sought in all eligible publications concerning:

- PICOS: Patient/Population/Problem – Intervention – Comparison – Outcome – Study type
- SSG design variables: Player number, (relative) pitch size, work-rest ratio (W:R), playing bouts, coach encouragement, and playing rules
- Outcome measure variables: Physical (RPE, injury), physiological (HR, blood lactate), and kinematics (GPS, gyroscope, accelerometer)
- External validity: Overall methodological robustness, applicability, and generalisability
- Internal validity: Risk of bias (RoB) in individual and across studies
- Study limitations
- Funding sources and conflicting interests

4.2.8 Risk of bias in individual studies

Thorough consideration was given to the vulnerability of sport and exercise medicine research to bias, and consequently the necessity for adequate bias assessment [309, 310]. Evidence of bias and its impact has been empirically shown in randomised controlled trials (RCTs), considered the golden standard [311]. Imprudent RoB assessment in non-randomised studies of intervention (NRSI) is also evident, with potential biases being greater compared to randomised studies [312]. Despite critical appraisal being common, it is less so in NRSI. Currently, in literature reviews, study quality assessment has been deemed heterogeneous, and lacking consensus on best practice [313]. Of note is that RoB is commonly mistaken for or conflated with study quality [312-315].

To our knowledge, there are currently no universally accepted standards for assessing RoB and quality in sport science. Thus, various appraisal methods were explored. Several RoB [316-320] and quality-assessment tools [321-326] were found to be inadequate for this specific review. Though not context-specific, ROBINS-I was implemented, as recommended in the Cochrane Handbook for Systematic Reviews of Interventions [327].

To our best judgement, the ROBINS-I tool provided the most rigorous and comprehensive RoB assessment for this review, despite its challenges [318, 320, 327-330]. The research group had no prior ROBINS-I-specific experience but was well-versed in critical appraisal and the systematic review process. The assessors were thereby experts in the field of rugby and SSG. Ample time and measures were taken to get familiarised and study ROBINS-I, ensuring sufficient methodological and content expertise, as requested by the Cochrane Collaboration [307, 327, 329].

ROBINS-I offers a framework for domain-based RoB assessment of NRSI in systematic reviews. Thus, focussing on studies' internal validity, its primary area of application is clinical health-based interventions. The underlying rational is to compare studies against their hypothetical ideal target RCT. This process is completed separately for every outcome measure of interest, evaluating seven domains of bias, per study involved. ROBINS-I allows for the incorporation of interventional, as well as observational-labelled studies, on the condition of a defined starting date [312, 329].

Outcome ratings for RoB included the following options: (1) Low RoB (the study is comparable to a well-performed randomized trial); (2) Moderate RoB (the study provides sound evidence for a non-randomized study but cannot be considered comparable to a well-performed randomized trial); (3) Serious RoB (the study has some important problems); (4) Critical RoB (the study is too problematic to provide any useful evidence and should not be included in any synthesis); and (5) No information on which to base a judgement about risk of bias.

Two researchers (K.W. & T. M.) completed the RoB assessment independently, for all included publications [331]. Individual raters' original detailed RoB assessments are available in Appendix 6: Risk of bias assessment (i.e., rater 1: official format rater 2: adapted format). Where domain-specific RoB judgements did not match between raters, consensus was reached through discussion of the respective signalling questions. Table 13 details the RoB per study outcome measure. An "overall RoB label" was given per study in Table 9, representing the studies' most at risk outcome measures.

To provide a comprehensive evaluation of the available literature, study quality was also rated. For this, preference was given to a sport science-specific method. Both Brughelli and colleagues' 10-item scale [332], and Sarmento's and colleagues' "16-item risk-of-bias quality form" [59, 242] were adopted. Based on the Delphi, PEDro, and Cochrane scale, and on Law and colleagues (1998), these scales were adapted for rating methodological quality of exercise training and match-analysis studies [242, 332]. These scales have been applied in rugby and soccer-related SSG research [59, 333]. A very high inter-observer reliability Kappa index of 0.97 (95% CI [0.97-0.98]) has been reported for Sarmento's quality form [242]. This combination of scales was adjudged to provide a context-specific critical appraisal process. The 10-item scale criteria were scored 0 (clearly no), 1 (maybe), or 2 (clearly yes). Whereas, the 16-items' required 0= no, 1= yes, or NA= not applicable (Appendix 7: Study quality assessment tools). Quality assessment outcome-classification guidelines were: low methodological quality (≤50%); good methodological quality (51%-75%), and; excellent methodological quality (>75%) [242].

Both quality assessment tools were individually applied to the included publications by two researches (K.W. & T. M.) independently, as prescribed in the literature [331]. Detailed individual rater quality scores are reported in Table 12. Following comparison, outcomes in study quality scores deemed too far apart, were discussed for a more uniform rating. The average of the inter-rater scores was reported as overall quality rating percentages in Table 9.

Results of RoB and quality assessment should be viewed independently, nevertheless complementing one another, noting that quality assessment has not been standardised in sport science. Furthermore, RoB is essential to overall study quality, since it measures internal validity. A visual RoB summary is presented in Figure 8.

4.2.9 Summary measures

Differences in mean values between SSG formats in physiological, physical, and kinematic outcome variables were the primary measures of interest. The intended summary effect measures for the following variables were sought to be significant at $\rho<0.05$, or assessed based on a statement of effect size (ES):

- Relative average heart rate, i.e., % HR_{MAX}
- Relative time spent in HR_{Z}
- V_{AVG}
- Relative speed (V_{REL})
- V_{MAX}
- Relative time spent in V_{Z}
- TD
- RD
- Distance covered in V_{Z}
- RPE
- Number of impacts per intensity zone ($Impact_{Z}$)

An overview of the inclusion of these outcome measures into the studies, and measures of secondary interest, is presented in Table 10 and Table 11. These overviews provide an insight into the consistency with which outcome variables within SSG^{RU} research are investigated.

4.2.10 Synthesis of results

Emphasis was placed on outlining the available evidence, and framing it in the current body of knowledge, to evaluate its quality and applicability to research and practice. Data were first interpreted, and individual study results narrated. An outcome variable-specific overview of study results is presented in Table 14. Absolute values were transposed to relative units where necessary, to facilitate meaningful comparison between studies. The data was then discussed to include critical assessment of the available evidence as well as its methodological make-up. Design and measurement-related parameters applicable to the research were considered (Table 10 & Table 11). Therefore, the studies were grouped by design, i.e. interventional vs. observational, and based on research aim, i.e. chronic vs. acute effects [308]. Grouped publications were handled by matching outcome variables for a meaningful synthesis. Quality assessment is reported in Table 9 and Table 12, and discussed thereafter. RoB assessment is summarised in a RoB graph (Figure 8). Due to the limited amount of included studies and large heterogeneity in methodological approach between these studies, no assessment of consistency of results was performed [314]. An overall summary of the evidence is provided in the closing take away message.

4.2.11 Risk of bias across studies

The results and methodology of the included studies were scrutinised to examine the possibility of bias across studies. Special attention was directed towards forms of potential bias, identified prevalent in the literature, or deemed important in sport science research; sampling bias (cf. external validity), selection bias (cf. internal validity), performance bias, attrition bias, detection bias, publication bias, selective reporting, lack of allocation concealment, and conflict of interest [331, 334-336]. To detect evidence of missing outcomes or abnormalities, every study's result and conclusion section was compared to their respective methods section or protocol. Additionally, explicit statements of funding were sought, as well as indications of overlapping roles (i.e., authors-coach), targeting conflicting interests. A visual representation of the distribution of RoB per domain across studies was generated using robvis software (Figure 9 and Figure 10) [337].

4.2.12 Additional analyses

Considering this systematic review's overall objective of providing an insight into the application of SSG to RU, a holistic perspective on SSG^{RU} research methodology required reporting the inclusion of SSG design variables, and specific study outcome variables, HR_Z, and V_Z. These data are made available in Table 10 and .

The additional search performed to update the state of the literature between the starting and ending phase of this doctoral investigation revealed new developments. To provide a complete insight, an exception was made for eligibility criteria 3 (male RU players) when all other criteria were fulfilled, in view of the study's informative contribution to the body of knowledge. The recent evolution of the evidence was analysed and chronologically narrated in section 4.3.7 Additional analysis.

4.3 Results

4.3.1 Study selection

One hundred and thirteen studies were identified in the initial search and two were added post-search. Of these, 49 duplicates were removed, one of which was identified as a different publication. Forty-four publications were inaccurate search records, with 42 publications remained after screening. Of these, 35 of these articles were excluded as they did not meet the final inclusion criteria. Seven studies fulfilled all five eligibility criteria: Gamble (2004) [163], Kennett, Kempton & Coutts (2012) [88], Vaz et al. (2012) [149], Vaz, Figueira & Gonçalves (2015) [338], Vaz et al. (2016) [87], Tee, Lambert & Coopoo (2016) [28], and Weakley et al. (2019) [339]. An overview of the study selection process is presented in Figure 7.

4.3.2 Study Characteristics

Table 9 presents an overview of the main characteristics of the included studies. All seven studies included SSG-play in their research and used similar technology to measure physical, physiological, or kinematic outcomes. The structure and approach towards investigating was different between studies. Further details about individual measures reported and SSG protocols used, are provided in Table 10 and Table 11.

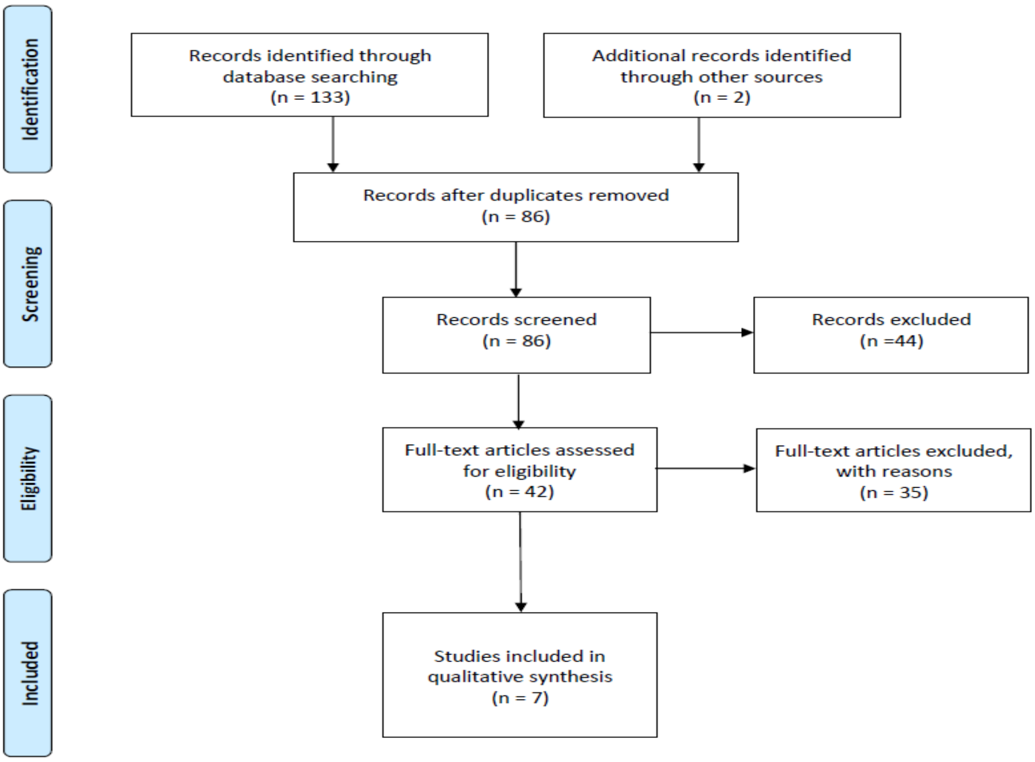

Figure 7 Flow diagram illustrating the phases of the search and selection of the studies: adapted from Moher et al. (2009)

67

Table 9 Study characteristics

Study (year)	Subject description	Study design[a]	Research aim	Experimental approach	SSG protocol	Quality (%)*		RoB[#]
Gamble (2004)	– n = 35 – Elite-level senior professional males representing 1 English Premier league team – Age: 27.61 ± 4.2 yrs – Stature: 185.42 ± 7.27 cm – Body mass: 98.61 ± 13.74 kg	– Quasi-experimental – Interventional – Longitudinal – One-way repeated within-subject measures design over time	Describe effects of SSG on endurance fitness in elite-level RU players	– 1 experimental group – SSG intervention, no other training – 9 weeks pre-season	Using elements of grid-iron/netball/soccer.	69	84	Critical
Kennett, Kempton, & Coutts (2012)	– n = 20 – Semi-professional males – Age: 21.3 ± 1.2 yrs – Stature: 183 ± 5 cm – Body mass: 89 ± 8 kg	– (Quasi-)[b] experimental – Interventional – Cross-sectional – Two-way (2x3) factorial repeated measures design	Describe effects of prescriptive variables on the training stimulus during SSG^{RU}	– 1 experimental group – 2x (3 SSG on 2 pitch sizes) as part of training session – 8 weeks in-season	4 v 4 – 6 v 6 – 8 v 8 32 x 24 m – 64 x 48 m 2 x 9 mins Modified touch rugby. Coaching allowed	90	67	Moderate
Vaz et al. (2012)	– n = 40 – Novice males (< 1y RU experience), 20 experienced males (> 5y (inter)national level) – Age: 21.6 ± 3.6 yrs – Stature: 177.7 ± 7.4 cm – Body mass: 81.2 ± 10.2 kg	– Quasi-experimental – Interventional – Cross-sectional – Non-equivalent two-group single factor design	Compare physical exertion and game performance indicators of experienced and novice RU players in SSG	– 2 experimental groups (novice < 1y & experienced > 5y) – 8 SSG in 4 test sessions – 4 weeks	6 v 6 60 x 40 m 1 x 12 mins 2011 IRB rules Encouragement allowed	73	63	Critical
Vaz, Figueira & Gonçalves (2015)	– n = 28 – U16 (n = 13) and U18 (n = 15) male youth representing 1 national level RU team – Age: 15.1 ± 0.6 yrs (U16); 16.8 ± 0.6 yrs (U18) – Stature: 175 ± 0.7 cm (U16); 178 ± 0.6 cm (U18)	– Observational – Cross-sectional – Cohort study	Investigate the demands of, and classify youth RU players by training performances, to establish whether these criteria can be used to group players instead of age group-criteria.	– 2 experimental groups (U16/U18) – 8 randomly selected full training sessions – 2 weeks in-season	6 v 6 warm-up + unspecified games 40 x 60 m (total pitch) 60 mins (total time)	65	53	Critical

	– Body mass: 67.6 ± 12.6 kg (U16); 77.7 ± 8.6 kg (U18)							
Vaz et al. (2016)	– n = 14 – Elite-level senior males representing 1 national Championship team – Age: 22.4 ± 3.2 yrs – Stature: NS – Body mass: NS	– (Quasi-)[b] experimental – Interventional – Cross-sectional – Three-way (3x3x3) nested factorial design	Investigate the influence of SSG on physical and physiological demands in RU players	– 1 experimental group – 4 x 1 SSG on 2 pitch sizes + 4 other training sessions per week – 6 months in-season period, Oct. 2012-March 2013, consecutive SSG within 4 weeks.	1 v 1 & 2 v 1 evasion, 30 x 30 m, 1 x 15 min - 7 v 7 possession & contesting, 50 x 35 m, 1 x 15 mins - 7 v 7 Sevens rules 100 x 70 m, 2 x 7 mins - Encouragement allowed.	68	52	Critical
Tee, Lambert & Coopoo (2016)	– n = 53 – Male professionals representing 1 South African RU team – Age: 25 ± 3 yrs – Stature: 186 ± 7 cm – Body mass: 101.5 ± 12.2 kg	– Observational – Cross-sectional[c] – Cohort study	Determine the specificity of typical training activities in RU, by comparison with the demands of match-play	– 4 conditions (HIIT – TEC – GBT – SKILL) – 96 full training sessions, 8 of which contained 86 GBT activities – 25 months (09/2011-10/2013), incl. 2 pre + 2 in-season phases	Unspecified	73	75	Critical
Weakley et al. (2019)	– n = 20 – university male RU players recruited from a British Universities and colleges Sport squad – Age: 19.8 ± 0.8 yrs – Stature: 1.81 ± 0.05 cm – Body mass: 96.8 ± 15.8 kg	– Quasi-experimental – Interventional – Cross-sectional – Reverse counterbalanced design	Investigate if providing GPS-based feedback to players in between bouts of SSG altered the locomotor, physiological, and perceptual responses in RU players.	– 2 experimental conditions (feedback - no feedback), containing 2 position-matched teams each – 6 separate testing sessions; baseline physical testing, SSG familiarisation, 4 SSG testing sessions (8 SSG) – 3-week pre-season period (September)	5 v 5 40 x 20 m 6 x 4 mins ‘Off-side’ touch rugby Between-bout kinematic feedback.	98	92	Moderate

***Recalculated based on applicable criteria of Brughelli’s 10-point scale [332] and Sarmento’s 16-item risk of bias quality form [59], respectively; #ROBINS-I overall Risk-of-Bias assessment for study outcome measures most at RoB; Moderate RoB (the study provides sound evidence for a non-randomized study but cannot be considered comparable to a well-performed randomized trial);) Critical RoB (the study is too problematic to provide any useful evidence and should not be included in any synthesis); [a] Based on proposed taxonomies of study designs by Portney & Watkins [340, 341], and Deeks & colleagues [342]; [b]Incomplete or unclear reporting of information to determine degree of experimental control with certainty (cfr. randomisation of allocation to groups or conditions, and/or inclusion of comparison groups); [c]Reported as longitudinal.

Abbreviations: RoB = Risk of Bias; NS = not specified; HIIT = high-intensity interval training; TEC = traditional endurance conditioning; GBT = game-based training; SKILL = game skill training/match-related drills

68

Table 10 SSG outcome measures inventory

Study (year)	Physiological						Kinematical										Physical	
							VA	Portable Microsensor device (GPS / ACCEL / GYRO)										
	HR_{AVG}	HR_{REST}	$\%HR_{MAX}$	$\%HR_{RECOV}$	HR_Z	Blood lactate		V_{AVG}	V_{MAX}	V_{PEAK}	$\%V_{MAX}$	V_{REL}	V_Z	TD	RD	$Impact_Z$	RPE	Injury
Gamble (2004)	×	✓	✓	✓	×	×	✓[a]	×	×	×	×	×	×	×	×	×	×	×
Kennett, Kempton, & Coutts (2012)	×	×	✓	×	✓	✓	×	✓	✓[b]	×	×	✓	✓	×	✓	×	✓[c]	×
Vaz et al. (2012)	×	×	×	×	✓	×	✓	×	×	×	×	×	✓	✓	×	✓	×	×
Vaz, Figueira & Gonçalves (2015)	×	×	×	×	✓	×	×	×	×	×	×	×	✓	✓	×	✓	×	×
Vaz et al. (2016)	×	×	×	×	✓	×	×	×	×	×	×	×	✓	✓	✓	✓[d]	×	×
Tee, Lambert & Coopoo (2016)	×	×	×	×	×	×	×	×	✓	✓	×	×	✓	✓	✓	×	×	×
Weakley et al. (2019)	×	×	✓[e]	×	×	×	×	×	✓	×	×	×	✓	✓	×	×	✓[f]	×

[a]Unspecified use, results not reported; [b]Reported as "peak sprint speed" and "peak speed"; [c]$RPE^{6\text{-}20}$; [d]Relative impacts (min^{-1}); [e]$TRIMP_{mod}$; [f]$dRPE^{CR100}$ (RPE-L + RPE-B). **Abbreviations**: VA= video analysis; HR_{AVG}= average heart rate; HR_{REST}= resting heart rate; $\%HR_{MAX}$= percentage of maximal heart rate; $\%HR_{RECOV}$= percentage of heart rate recovery; HR_Z= heart rate zones; $RPE^{6\text{-}20}$= rating of perceived exertion (Borg scale 6-20); GPS= global positioning system; ACCEL= accelerometer; GYRO= gyroscope; V_{AVG}= average speed; V_{MAX}= maximal speed; V_{PEAK}= peak speed; $\%V_{MAX}$= percentage of maximal speed, V_{REL}= mean relative speed; V_Z= speed zones; TD= total distance; RD= relative distance; $Impact_Z$= number of impacts per intensity zones; $TRIMP_{mod}$= Stagnos heart rate training impulse (AU); $dRPE^{CR100}$ (RPE-L + RPE-B)= differential ratings of perceived exertion (centi-max scale for leg muscle exertion and breathlessness); NS= mentioned, but not specified numerically

Table 11 SSG design variables & measurement zones

Study (year)	Player Nº	Pitch size (m)	Relative pitch area (m^2/player)	Game duration [W:R (mins)]	Playing bouts	Coaching Encouragement	Playing rules	HR_Z (Nº)	V_{ZONES} (Nº)
Gamble (2004)	NS[#]	NS[#]	-	NS	NS	Retrospective player-specific video analysis of involvement	NS – emphasis on keeping intensity high. (Elements of grid-iron, netball, and soccer)	-	-
Kennett, Kempton, & Coutts (2012)	4v4 6v6 8v8	32x24 (S) 64x48 (L)	S: 96- 64- 48 L: 384- 256- 192	9:2[NS]	2	Yes	Modified rugby touch rules: – 6 plays – 1 hand touches – Backwards passing 5m defensive line – "play the ball"	3[A]	4[D]
Vaz et al. (2012)	6v6	60x40	200	12:0	1	Yes but no feedback	2011 IRB rules	4[B]	6[E]
Vaz, Figueira & Gonçalves (2015)	6v6 warm-up + various SSG (NS)	NS	-	NS	NS	NS	Touch rugby warm-up Other SSG NS	4[C]	6[F]
Vaz et al. (2016)	1v1 2v1 7v7 7v7	30x30 30x30 50x35 100x70	450 300 125 500	15:0 15:0 15:0 7:1[PR]	1 1 1 2	Yes but no feedback	– Evasion skills – Evasion skills – Union rules (possession-contesting focussed) – Sevens rules	4[B]	6[E]
Tee, Lambert & Coopoo (2016)	NS	NS	-	NS	NS	NS	NS	-	4[G]
Weakley et al. (2019)	5v5	40x20	80	4:2[PR]	6	Verbal feedback (distance per player) provided between bouts for feedback condition. Within-bout coaching NS.	'off-side' touch rugby	-	2[H]

Abbreviations: NS= not specified; PR= passive rest; MSS= maximal sprint speed; [#](including elements of grid-iron, netball, and soccer)
Heart rate zones *(%HR_{MAX})*:
[A][0-75%; 75-84%; ≥85%],
[B][0-75%; 75-84.9%; 85-89.9%; ≥90%],
[C][0-75% ("zone 1"); 75-84.9% ("zone 2"); 85-89.9% ("zone 3"); ≥90% ("zone 4")]
Speed zones *($km \cdot h^{-1}$)*:
[D][0-6.9 ("standing & walking"); 7-14.4 ("jogging"); 14.5-23 ("high-speed running"); >23 ("sprinting")],
[E/F][0-6.9 ("standing still & walking" / "zone 1"); 7-9.9 ("jogging" / "zone 2"); 10-12.9 ("cruising" / "zone 3"); 13-15.9 ("striding" / "zone 4"); 16-17.9 ("high-intensity running" / "zone 5"); ≥18 ("sprinting" / "zone 6")],
[G][0-7.2[a] ("walking"); 7.2-14.4[a] ("jogging"); 14.4-21.6[a] ("striding"); >21.6[a] ("sprinting") - [a]Converted from $m \cdot s^{-1}$],
[H][<61% MSS ("low-speed distance"; ≥61% MSS (high-speed distance")]

70

4.3.3 Risk of bias within studies

Studies' overall ROBINS-I ratings are available in Table 9. These ratings are dictated by each study's domain most at RoB. To avoid misinterpreting or undervaluing the research's contribution, we recommend interpreting RoB per RoB domain, for every outcome measure (Table 13). Figure 8 summarises this RoB visually [337]. An in-depth breakdown of the individual raters' ROBINS-I assessment processes is available in Appendix 6: Risk of bias assessment.

In conjunction, the studies' methodological quality forms an extra source of information regarding its overall make-up. Discrepancies between scales and raters were reported in Table 12. Additional details can be found in Appendix 7: Study quality assessment tools.

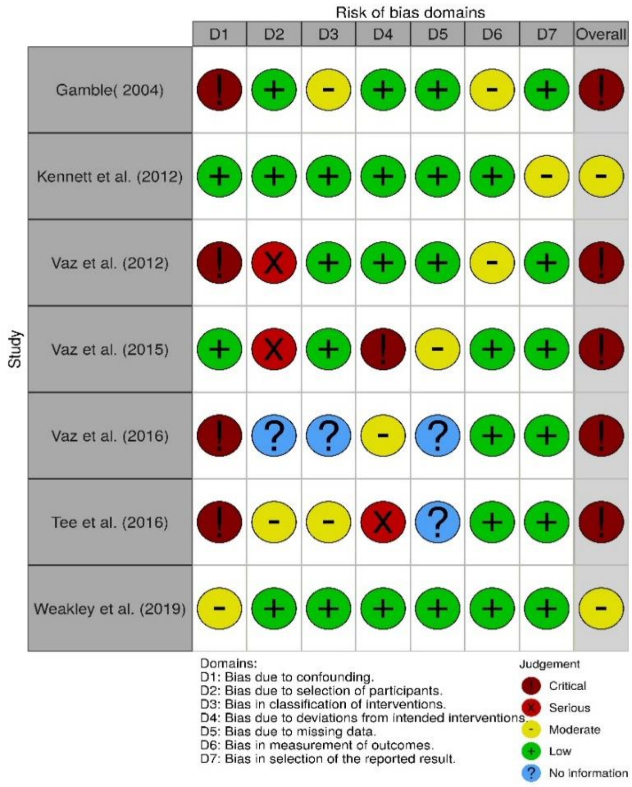

Figure 8 ROBINS-I risk of bias assessment

Table 12 Intra-rater study quality assessment sum scores

Quality assessment tool	Sarmento et al. [242] *(max. 16)*		Brughelli et al. [332] *(max. 20)*	
Study	**Rater1**	**Rater2**	**Rater1**	**Rater2**
Gamble (2004)	14	13	13*	12*
Kennett, Kempton, & Coutts (2012)	10.5	11	18	18
Vaz et al. (2012)	10	10	15	14
Vaz, Figueira & Gonçalves (2015)	8	9	13	13
Vaz et al. (2016)	7.5	9	13	14
Tee, Lambert & Coopoo (2016)	12	12	15	14
Weakley et al. (2019)	14.5	15	20	19

*out of 18 I/O 20 (1 item NA)

Table 13 Individual study Risk of Bias (RoB) assessment per RoB domain

Domains of bias	Gamble (2004)	Kennett et al. (2012)				Vaz et al. (2012)			Vaz et al. (2015)		Vaz et al. (2016)		Tee et al. (2016)	Weakley et al. (2019)		
Outcome measure	**HR**	**HR**	**GPS**	**RPE**	**BLa^-**	**HR**	**GPS**	**VA**	**HR**	**GPS**	**HR**	**GPS**	**HR**	**HR**	**GPS**	**RPE**
1 Confounding	C	L	L	L	L	C	C	C	L	L	C	C	C	M	M	M
2 Selection	L	L	L	L	L	S	S	S	S	S	NI	NI	M	L	L	L
3 Classification of intervention	M	L	L	L	L	L	L	L	L	L	NI	NI	M	L	L	L
4 Deviation of interventions	L	L	L	L	L	L	L	L	C	C	M	M	S	L	L	L
5 Missing data	L	L	L	L	L	L	L	L	M	M	NI	NI	NI	L	L	L
6 Measurements of outcomes	M	L	L	L	L	M	M	M	L	L	L	L	L	L	L	L
7 Selection of reported result	L	M	M	M	M	L	L	L	L	L	L	L	L	L	L	L
Overall Risk of Bias	**C**	**M**	**M**	**M**	**M**	**C**	**C**	**C**	**C**	**C**	**C**	**C**	**C**	**M**	**M**	**M**

L = low; M = moderate; S = serious; C = critical; NI = no information/incomplete information; HR = heart rate; GPS = global positioning system; RPE = rating of perceived exertion; BLa^- = blood lactate; VA = video analysis

72

4.3.4 Results of individual studies

Multiple physiological (HR, blood lactate), kinematic (video analysis, microsensor device), and physical (RPE) measures were used in the studies to report results. Despite the overarching research topic and similar measurement technology used, individual reporting of results was varied. Consequently, a comparative overview of results was given per study (Table 14). Seven studies were identified, totalling 210 participants from heterogenous samples: widely ranging in age, nationality, experience, and playing level. These studies are discussed individually hereafter.

Gamble (2004) conducted a quasi-experiment, exposing an senior elite RU team to a combination of SSG for conditioning purposes [163]. Following an adaptational significant drop in $\%HR_{MAX}$ from week 1 to 2 ($\rho<0.01$), further declines from week 2 were seen for week 4, 5, 7 ($\rho<0.05$), and week 9 ($\rho<0.01$). Week to week, $\%HR_{MAX}$ fell between week 1 and week 2, rose on week 5 and 6, to fall again on week 6 and 7 ($\rho<0.01$). After initial adaptation, $\%HR_{RECOVERY}$ saw significant rises compared to week 2 for week 7 and the first week of in-season ($\rho<0.05$), and for week 9 ($\rho<0.01$). Weekly jumps occurred between week 1 and 2, and week 6 and 7 ($\rho<0.01$). Exertion testing showed improvements from 94.9 ± 2.8 $\%HR_{MAX}$ for existing players and 97.5 ± 1.1 $\%HR_{MAX}$ for new players pre-intervention, to 88.5 ± 3.6 $\%HR_{MAX}$ for the group mean, post-intervention. Observed differences between playing positions, for the rate and magnitude of improvements, could not be validated statistically due to insufficient numbers in each positional group [86].

Time-motion demands were found to be different between several SSG formats by Kennett, Kempton, and Coutts [88]. Mean speeds of 114 ± 16, 110 ± 15, and 100 ± 16 $m \cdot min^{-1}$ were recorded for 4 v 4, 6 v 6, and 8 v 8, respectively ($\rho<0.05$). The HSR distances also decreased significantly ($\rho<0.05$), with 273 ± 179, 199 ± 129, and 153 ± 115 m, for the same SSG as player number increased. The 4 v 4 format produced 2.1 ± 2.4 sprints, as opposed to 1.0 ± 1.2 for 8 v 8 ($\rho<0.05$). A large pitch size showed higher V_{AVG} (121 ± 10 and 94 ± 9 $m \cdot min^{-1}$), HSRD (316 ± 120 and 88 ± 49 m), and sprints (2.5 ± 2 and 0.4 ± 0.7), but lower V_{PEAK} (21.3 ± 2.7 and 25.8 ± 2.7 $km \cdot h^{-1}$) than a small pitch size ($\rho<0.05$). When looking at physiological and perceptual differences, Kennett and colleagues [88] found 4 v 4, 6 v 6, and 8 v 8 to have similar $\%HR_{MAX}$ (88.8 ± 5.9; 88.4 ± 5.7; 87 ± 5.1, respectively) and % of time spent above 85% of HR_{MAX} (74.5 ± 31.2; 72.1 ± 34.3; 70.3 ± 29.6, respectively).

There were no significant differences observed when field size was considered (86.7 ± 6.0, 89.4 ± 4.8 %HR_{MAX} and 64.4 ± 36.4, 79.9 ± 23.8 %time >85% HR_{MAX}, for small vs. large fields, respectively; ρ< 0.05). In contrast, less players led to significantly higher RPE (17.4 ± 1.4, 15.0 ± 1.8, and 12.7 ± 2.5; ρ< 0.05) and blood lactate (4 v 4: 8.9 ± 3.2 vs 6 v 6: 6.5 ± 3.0 and 8 v 8: 6.0 ± 3.7 $mmol\cdot L^{-1}$; ρ< 0.05) , as did a large pitch size (13.7 ± 2.7 vs. 15.8 ± 2.2 RPE, and 5.7 ± 3.3 vs. 8.2 ± 3.4 $mmol\cdot L^{-1}$) (ρ< 0.05). The correlation between relative pitch area (m^2/player) in all SSG on the one hand, and kinematics, RPE, and blood lactate responses on the other, were large to very large (total distance: r=0.88, HSRD: r=0.87, mean speed: r=0.87, number of sprints: r=0.67, V_{PEAK}: r=0.63, session-RPE=0.59, and blood lactate: r=0.48; all ρ<0.05). For HR measures, trivial correlations were found between relative pitch area and <75% HR_{MAX} (0.03), 75–85% HR_{MAX} (0.09), and >85% HR_{MAX} (0.08) (all ρ>0.05). All SSG' movement demands were highly reproducible, when repeated twice per format in random order over an eight-week period, as shown by the outcome measures' inter-class correlation (ICC) ± 90% confidence interval (CI): TD = 0.90 (0.82–0.95), mean speed 0.87 (0.76–0.93), and HSR 0.90 (0.82–0.95).

In their attempt to establish the physical and performance-related differences between novice and expert senior RU players during 6 v 6, Vaz and colleagues reported that, regarding V_Z "the single effect of partial distances was statistically significant, with pairwise differences in all, with an exception being made in the pair Zone 2 vs. Zone 3" (ρ<0.001) [89]. Considering "no significant interaction with group" was found, respective distances for novices vs. experienced senior players are understood to be equal for all V_Z, including "standing still and walking" (549.9 ± 55.1 vs. 551.2 ± 57.6 m), "High-intensity running" (49.0 ± 25.5 vs. 52.6 ± 23.3 m), as well as "sprinting" (94.0 ± 73.8 vs. 99.1 ± 61.1 m). Similar TD was covered by novice (1176.2 ± 168.6 m) and experienced senior players (1226.9 ± 145.9 m). An identical outcome was given for % of time in V_Z (ρ<0.001), with "pairwise differences in all pairs", and "no significant interaction". For % of time in HR_Z, the researchers found "the single effect was significant with pairwise differences in all pairs" (ρ<0.001), but there was "no interaction with group". Novice players spent most of the playing time, respectively 1.9 ± 1.0 and 7.9 ± 2.1 minutes of the twelve-minute game (~82%), between 85-89.9% HR_{MAX} and 90% HR_{MAX}. Similarly, experts spent 2.1 ± 0.9, and 8.1 ± 2.1 minutes (~85%) of playing time in $HR_{Z3\text{-}4}$. Partial impacts were noted to have "a significant single effect, with pairwise differences in all, exception made in the pairing of Zone 2 vs. Zone 4" (ρ<0.001). Again, "no significant interaction with group", nor differences for total impacts between groups were observed. Most impacts (~101 of 190) for novices were found spread out through the medium zones ($Impact_{Z2\text{-}5}$; i.e., 6.1-10 g), whereas experienced players registered mostly (~87.1 of 183) very light impacts ($Impact_{Z1}$; i.e., "<5.0-6.0 g").

Novices also experienced more severe impacts ($Imapct_{Z6}$; i.e., ≥10.1 g) than experienced players (4.7. ± 9.1 (~2.5% of total) vs 1.6 ± 2.4 (0.9%)). However, no significance was established. Expert players showed better performance indicators compared to novices in terms of passes (58.5 ± 23.2 vs. 37.5 ± 13.0), tackles made (48.7 ± 3.3 vs. 28.2 ± 3.3), and tries scored (7.2 ± 2.3 vs. 4.5 ± 2.3) (ρ<0.001).

Within an observational design, Vaz and colleagues (2015) used a two-step cluster with log-likelihood as the distance measure and Schwartz's Bayesian criterion, to find RU youth players could alternatively be differentiated into training performance-based groups; cluster 1 (n=12 U16 + 4 U18= 57.1% total participants) vs. cluster 2 (n=1 U16 + 11 U18= 42.9% total participants) [306]. Cluster 1 had a significantly lower mean age and BMI, as compared to Cluster 2 (ρ<0.001). The best predictor for group classification was HR, namely HR_{Z1} (Predictor Importance [PI]=1), HR_{Z2} (PI=0.97), HR_{Z4} (PI=0.63) (see Table 11 for HR_Z). Players in both clusters clearly covered most distance between 0 – 6.9 $km{\cdot}h^{-1}$. From graphical display, this was estimated to be a TD of approximately 1500 to 1700 m. Partial distances saw a gentle stepwise decrease, for increasing V_z. In this regard, the researchers reported significant pairwise differences in all zones between clusters (ρ<0.01). A parallel evolution was observed for both groups concerning body impacts and HR, with most impacts (≈165-210) registered between 5 and 6 g. The majority of training time (Cluster 1≈20 min, Cluster 2≈37 min) was spent below $75\%HR_{MAX}$, with "no pairwise difference between HR_{Z3} and HR_{Z4}". According to these performance parameters, 18% of participants were misclassified when based on age.

The investigation by Vaz et al. (2016) into the physiological and kinematic demands of different SSG formats on senior RU players, demonstrated statistically meaningful differences [87]. Specifically, for 1v1 and 2v1 (30 x 30 m, evasion), and twice 7v7 (35 x50 m vs 70 x 100 m, official rules), a significant effect of V_Z was stated (ρ<0.001), with pairwise differences between all zones with exception of z2-z3 and z5-z6. Additionally, the interaction between V_Z and the formats of the SSG was reported to be significant (ρ<0.001). Overall RD was found to be similar for all SSG, with graphs providing an estimation of between 4 to 11 $m{\cdot}min^{-1}$. On the other hand, relative impacts, visually estimated to be 9 min^{-1}, were reported significantly lower in 1v1, in comparison to the other three SSG (ρ<0.001). Regarding impacts in the six defined g-force zones, Vaz and colleagues also reported a significant effect of zone (ρ<0.001), with pairwise differences in all zones, except between z2-z4 and z5-z6 [87]. Furthermore, differences were found in the interaction between impact zones and SSG formats, with exceptions for 2v1 and 7v7 ½ pitch , 2v1 and 7v7 full pitch , and 7v7 ½ pitch and 7v7 full pitch (ρ<0.05). These results suggest significantly more impacts (approx. 32–45), occur in the 5–6 g range for all SSG (ρ<0.001).

The HR values too, showed significant effects of zones (ρ<0.001), with no differences for interaction with SSG formats. Within each of the four categories, time spent in HR_Z was similar when comparing between SSG formats. Nevertheless, across all SSG formats, time in HR_{Z4} (≥90%HR_{MAX}) > HR_{Z3} (85-89.9 %HR_{MAX}) > HR_{Z2} (75-84.9%HR_{MAX}) > HR_{Z1} (<75%HR_{MAX}) (ρ<0.001). Depending on the format, approximately 3.25 to 4 out of 15 minutes (~22 -27% of total duration) were spent at or above 90% HR_{MAX}.

Tee and colleagues assessed four training modalities of a professional South-African rugby team using GPS and compared them to their kinematic match demands [28]. Training forms were classified by the researchers in consultation with the team's strength and conditioning coach; traditional endurance conditioning (TEC: maximal aerobic speed and interval running, no ball, 3-15 min, W:R 2:1 to 1:3), high-intensity interval training (HIIT: short-burst high-speed bouts, no ball, changes of direction, 20 sec – 2.5 min. W:R 1:1 to 1:10), game-based training (GBT: training games to improve physical qualities, skill, and decision making, i.e., SSG with varying design), and skills training (ST: match-specific skill components targeting coordinated play and proficiency under pressure). The match variables against which training was contrasted included: duration (73 ± 24 min), TD (5050 ± 1636 m), RD (69 ± 8 $m \cdot min^{-1}$), V_{MAX} (8.2 ± 1.3 $m \cdot s^{-1}$), Walking (34 ± 5 $m \cdot min^{-1}$), jogging (23 ± 6 $m \cdot min^{-1}$), striding (10 ± 4 $m \cdot min^{-1}$), sprinting (2.4 ± 1.9 $m \cdot min^{-1}$), sprint frequency (1 every 9 ± 13 min), and acceleration frequency (1 every 6 ± 10 min). The GBT results exceeded these match demands for duration (99 ± 19 min) and TD (5787 ± 1212 m) only, matched them for V_{MAX} (8.4 ± 1.3 $m \cdot s^{-1}$), striding (9 ± 3 $m \cdot min^{-1}$), sprinting (2.6 ± 2.3 $m \cdot min^{-1}$), sprint frequency (1 every 9 ± 11 min), and acceleration frequency (1 every 6 ± 11 min), but fell significantly short for RD (59 ± 9 $m \cdot min^{-1}$), walking (29 ± 5 $m \cdot min^{-1}$), and jogging (19 ± 6 $m \cdot min^{-1}$). For those components lagging in GBT, such as RD, TEC (92 ± 34 $m \cdot min^{-1}$) and HIIT (71 ± 21 $m \cdot min^{-1}$) performed better. Despite falling short, GBT elicited the greatest walking distance of all the training forms. In turn, TEC (44 ± 28 $m \cdot min^{-1}$) and HIIT (27 ± 16 $m \cdot min^{-1}$) elicited significantly more jogging than GBT. Of note, TEC (1 every 22 ± 8 min) and ST (1 every 14 ± 14 min) showed higher sprint frequencies, and TEC was the only training form with a greater acceleration frequency than match-play(1 every 23 ± 11. Overall, HIIT was most match-specific, followed by GBT. Conversely, TEC differed from match-play the most, both over and underreaching for specific movement variables. The ST also failed to meet match requirements for most movement categories, which is in line with expectations as ST does not primarily target movement and physical capacity. Training forms such as TEC and HIIT can be used to complement GBT in function of the match demands.

In addition to the general match demands, Tee and colleagues reported positional differences whereby GBT was the best fit for inside and outside backs, relative to their respective match demands [28]. Most training activities provided adequate HSR stimuli for tight forwards and loose forwards had similar results, except for GBT's lack of striding (ES=medium), and ST lacking jogging and striding distance (ES=large). All three, GBT, TEC, and ST showed large differences in most movement categories for scrum halves. For these playing positions, HIIT was most similar to match-play demands. Of note, no training activity met outside backs' V_{MAX} demands. These observations indicate no single training form, including GBT, will fully cover all players' kinematic match requirements and consequently, complementary training forms need to be considered per playing position. Depending on the playing position, the match demands reported can furthermore increase by up to 47% for walking and up to 41% for jogging, when comparing maximum values to average match-play. Striding and sprinting distance can increase by up to 75% and 270%, respectively. Sprint frequency (246%) and acceleration frequency (185%) can also increase, ranging widely between positions. Differences between GBT and maximum match values are nonetheless noted, e.g., for jogging (+46%), while other demands fall short. In contrast, TEC and HIIT show greater maximal values than match-play, for all measures, by up to 264% (striding distance). Therefore, a range of training modalities can be used strategically to train the most extreme match demands [28].

In testing "augmented feedback" on male university RU players (i.e., TD covered) during 5 v 5 'off-side' touch rugby (6 x 4 min, 2 min passive recovery, 20 x 40 m), Weakley and colleagues found possibly to very likely trivial ergonomic effects for feedback vs no feedback [339]. Specific kinematic measurements included TD (2200 ± 156 vs 2177 ± 186 m; ES= 0.15), low-speed running distance (2074 ± 152 vs 2046 ± 182; ES= 0.18), HSRD (126 ± 55 m vs 131 ± 67 m; ES= -0.07), MSS ((6.8 ± 0.6 $m \cdot s^{-1}$ both; ES= 0.11), and mean acceleration/deceleration (0.56 ± 0.06/0.05 $m \cdot s^{-2}$, both; ES=0.15). The effects on Stagno HR training impulse ($TRIMP_{mod}$) were very likely trivial (50 ± 13 vs 52 ± 20 AU; ES= -0.05). Leg muscle exertion (RPE-L) (50 ± 13 vs 50 ± 11; ES=-0.05) and breathlessness (RPE-B) (48 ± 12 vs 49 ± 12; ES=-0.09) were nearly identical between both conditions. Between-condition within-bout data only resulted "possibly greater" differences for low-speed distance in bout 2, (ES=0.23, 90% CI [0.01-0.46]), and in bout 4 for MSS (ES=0.21 [-0.04-0.45]). In other words, whole SSG performance was not uniformly increased or decreased by augmented feedback and possible ergogenic effects within bouts were limited to specific kinematic exceptions.

4.3.5 Synthesis of results

The systematic search resulted in seven studies meeting eligibility criteria. Within the studies, two observational designs, spreading from two weeks to 25 months in length, included 81 subjects [28, 338]. These investigations studied the specificity of SSG and other training forms in function of rugby demands, and potential alternative grouping methods in youth training. Furthermore, in five interventional studies including 129 subjects, the conditioning and skill-related effects, and the design of SSG were investigated [87, 88, 149, 163, 339]. This analysis was done both longitudinally and cross-sectionally, over periods from three weeks to six months. Within the latter studies, data was collected in pre and in-season. The heterogeneity seen across observations and interventions, reported outcomes, and measures used for it, disallowed meta-analysis (cf. PRISMA checklist [304]). A synthesis was provided in overview format of the main study results in Table 14, relative to their context. A narrated discussion of feasible comparisons is provided in 4.4 Discussion .

Table 14 Study results overview

Study (year)	SSG Conditions	Physiological–Perceptual	Kinematic-Skill
Gamble (2004)	Elite-Pro Seniors–1 experimental group SSG intervention, no other metabolic conditioning Elements of grid-iron/netball/soccer	↓%HR_{MAX} Wk 2-9** ↑%$HR_{RECOVERY}$[1] Wk 1-9**	
Kennett, Kempton, & Coutts (2012)	Semi-Pro Seniors 4 v 4 – 6 v 6 – 8 v 8 32 x 24 m & 64 x 48 m 2 x 9 min Modified touch rugby	BLa^- 4 v 4* > 6 v 6* > 8 v 8* BLa^- $S_{pitch} < L_{pitch}$* RPE^{6-20} 4 v 4* > 6 v 6* > 8 v 8* RPE^{6-20} $S_{pitch} < L_{pitch}$* %HR_{MAX} 4 v 4 = 6 v 6 = 8 v 8 %HR_{MAX} $S_{pitch} = L_{pitch}$ Time >85% HR_{MAX} 4 v 4 = 6 v 6 = 8 v 8 Time >85% HR_{MAX} $S_{pitch} = L_{pitch}$	V_{REL} 4 v 4* > 6 v 6* > 8 v 8* HSR 4 v 4* > 6 v 6* > 8 v 8* Sprints 4 v 4 > 8 v 8* V_{PEAK} 4 v 4 = 6 v 6 = 8 v 8 $S_{pitch} < L_{pitch}$ for all kinematic variables*
Vaz et al. (2012)	National or international level – 2 Groups Novice (<1y) vs. experienced (>5y) 6 v 6 – 60 x 40 m – 12 mins 2011 IRB-rules	V_Z Nov = Exp HR_Z Nov = Exp	Impacts Nov = Exp TD Nov = Exp, $Impact_Z$ Nov = Exp PI Exp > Nov**
Vaz, Figueira & Gonçalves (2015)	National level - Juniors U16 vs. U18 8 randomly selected full training sessions 40 x 60 m, 60 mins 6 v 6 warm-up + unspecified SSG	*Cluster 1 & 2:* Most playing time <75% HR_{MAX} Time HRz1 > HRz2 > HRz3 = HRz4*** Age cluster1 ≠ Age cluster2* BMI cluster1 ≠ BMI cluster2***	Distance $V_{Z1,2,3,4,5}$ Cluster1 > Cluster2** Impacts Cluster1 > Cluster2* PI_{HRz1} (1) > PI_{HRz3} (0.97) > PI_{HRz4} (0.63)
Vaz et al. (2016)	Elite – National level – Seniors SSG1 – 1 v 1 – evasion – 30 x 30 m – 15 min SSG2 – 2 v 1 – evasion – 30 x 30 m –15 min SSG3 – 7 v 7 – possession & contest – 50 x 35 m – 15 min SSG4 – 7 v 7 – sevens – 100 x 70 m – 2 x 7 min	SSG mostly ≥90% HR_{MAX} HR_Z ≠*** HRz4 (≥90%) SSG 1> 2 > 3 > 4	V_Z ≠*** (excl. z2-z3, z5-z6) $V_{Z1,2,3,6}$ SSG 1 < SSG 2,3,4 $V_{Z2,3,6}$ SSG 4 > SSG 1,2,3 RD SSG 1 = 2 = 3 = 4 Impacts z1 > z2,3,4,5,6 Impacts·min^{-1} SSG 1 < SSG2,3,4** $Impact_Z$ ≠* (excl.SSG 2-3,4 & SSG 3-4)
Tee, Lambert & Coopoo (2016)	Elite - Pro Seniors TEC vs. HIIT vs. GBT vs. ST vs. MATCH		Duration ST > GBT > MATCH,TEC,HIIT* TD GBT > ST,TEC,HIIT,MATCH* RD TEC > HIIT = MATCH > GBT > ST* V_{MAX} GBT > ST,TEC,HIT* V_{MAX} GBT = MATCH*

79

			RD V_{Z1}: MATCH > GBT = ST > TEC = HIIT* *RD V_{Z2}:* TEC > HIIT > MATCH > GBT > ST* *RD V_{Z3}:* TEC = HIIT > MATCH = GBT > ST* *RD V_{Z4}:* GBT = MATCH = HIIT > ST= TEC* Sprints GBT = MATCH = HIIT ≥ ST = TEC* Accel GBT = MATCH = HIIT = ST > TEC* TF ≠ LF ≠ SH ≠ IB ≠ OB
Weakley et al. (2019)	University-level Students Conditions: FB vs. NFB 5 v 5 – 40 x 20 m – 6 x 4 min ‘Off-side’ touch rugby Between-bout kinematic verbal feedback	*NFB = FB (ES)* $TRIMP_{mod}$: -0.05 [-0.17, 0.06] RPE-L: 0.05 [-0.21, 0.32] RPE-B: -0.09 [-0.32, 0.14]	*NFB = FB (ES)* TD: 0.15 [-0.03, 0.34] LSD: 0.18 [0.00, 0.37] HSD: -0.07 [-0.27, 0.13] V_{MAX}: 0.11 [-0.11, 0.34]) Accel/Decel: 0.15 [-0.03, 0.34]

*$\rho < 0.05$** $\rho < 0.01$*** $\rho < 0.001$

[1]Decline in HR from the end of the final shuttle test stage to the end of the final one-minute rest period, expressed as % of the player’s individual HRR

Abbreviations: HR = heart rate; HR_{MAX} = maximal heart rate; $HR_{RECOVERY}$ = recovery heart rate; HRR = heart rate reserve; HR_Z = heart rate zones; V_{REL} = mean relative speed; HSR = high-speed running distance; V_{PEAK} = peak speed; RPE^{6-20} = rating of perceived exertion (Borg scale 6-20); GPS = global positioning system; BLa^- = blood lactate; S_{pitch} = small pitch size; L_{pitch} = large pitch size; TD = total distance; RD = relative distance; $Impact_Z$ = impacts per intensity zones; PI = predictor importance; HR_{Zn} = heart rate zone n; $TRIMP_{mod}$ = Stagnos heart rate training impulse; RPE-L/RPE-B = differential ratings of perceived exertion (centi-max scale) for leg muscle exertion and breathlessness; LSD = Low-Speed Distance; HSD = High-Speed Distance; MSS = Maximal Sprint Speed; Acc_{MEAN}/Dec_{MEAN} = mean acceleration and deceleration; MATCH = match-play; TEC = traditional endurance conditioning; HIIT = high-intensity interval training; GBT = game-based training; ST = skills training; TF = tight forwards; LF = loose forwards; SH = scrumhalves; IB = inside backs; OB = outside backs; FB = feedback; NFB = no feedback.

80

4.3.6 Risk of bias across studies

The available literature shows bias management is inherently limited in competitive team sport environments. A clinical, true experimental approach is challenging to obtain, as it could interfere with the sports' natural characteristics. Despite these challenges, the utmost care should be taken to mitigate RoB in research, to obtain high-quality evidence. The targeted forms of potential RoB across studies were summarised in Table 15. Based on the studies' individual ROBINS-I assessments, the distribution of RoB judgements per bias domain was visualised in Figure 9, weighted across studies by proportion of subject contribution to the body of literature (%total participants), and unweighted in Figure 10 [337].

Table 15 Risk of bias across studies

	Gamble (2004)	Kennett et al. (2012)	Vaz et al. (2012)	Vaz et al. (2015)	Vaz et al. (2016)	Tee et al. (2016)	Weakley et al. (2019)
Sampling	Y	Y	Y	Y	Y	Y	Y
Selection	N	Y	N	Y	Y	N	N
Performance	Y	N	Y	Y	Y	Y	N
Attrition	N	Y	Y	Y	Y	N	N
Detection	N	N	N	N	N	N	N
Publication	N	N	N	N	N	N	N
Selective reporting	N	Y	Y	Y	Y	N	N
Allocation concealment	Y	Y	Y	Y	Y	Y	Y
Conflict of interest	Y	Y	Y	Y	N	N	Y
Funding	Y	N	Y	Y	N	N	Y

Y = Yes (At RoB; bias not comprehensively and explicitly accounted for); N = No (Not at RoB; bias comprehensively and explicitly accounted for)

A comparison of the studies' methods against their respective result and conclusion sections, generally showed most preconceived kinematic, physiological, perceptual, and skill-related variables were addressed. Some protocols were thereby more clearly stated than others, with possible limitations recognised [28, 86, 306, 343]. No studies included an exact report on their specific sampling processes. This leaves room to speculate about the samples' origin, e.g., befriended teams, professional or academic relations. Without specifying probability (random selection) or nonprobability sampling (non-random methods), potential sampling bias across studies cannot be determined accurately. As a case in point, stratified random and cluster sampling could be possible in all but one study [163]. However, convenience (i.e., availability) and purposive sampling were more likely to be the case.

Selection bias is internal to the study, and therefore does not address generalisability, applicability, nor transferability. It can occur when selection of eligible participants, follow up time, or specific outcome events, into a study, are related to both intervention and outcome [307, 327]. That is, an exclusion from conditions throughout the experiment would impact the relation between what is being studied, and its result. This underlines the essential necessity for researchers to clearly outline the selection mechanisms used throughout, when the study design does not provide self-evidency. For instance, a single condition uniformly implemented to all players equally (i.e., training session(s) or a specific SSG) facilitates selection interpretation [149, 163, 338]. In contrast, a collection of different SSG formats within rugby training session(s), requires specific and complete protocol details [28, 87, 88, 339]. However, this was not provided for, across studies. Self-selection can also be an issue when participants volunteer, as was the case in at least one study [28].

Eligible players' allocation was also not clearly reported and selective reporting was a concern, if instances of data collection were not used. Despite stratifying into subgroups [149, 338] and matching opposing teams [88, 339], several studies failed to specify the full extent of allocation processes into respective experimental conditions, i.e. for every SSG format [87, 88, 149]. Aside from one quasi-experimental and two observational designs looking at whole sessions, including all participants equally [28, 163, 338], only one study provided adequate detail [339]. Furthermore, just two studies explicitly reported attrition [28, 163]. Another study allowed attrition to be derived implicitly from its design and participant numbers [339]. It remains unclear throughout the literature to what extent, and on what basis, every participant within the sampled player group was actively involved; and furthermore, to what degree their data was used.

Methodological inaccuracies in study design, data collection, and reporting, including issues regarding unequal conditions, HR measurement, and study misclassification, limit the interpretation of the studies included [28, 86, 306]. Gaps were noted in numerical and graphical data, including indications of statistical significance. [87, 163, 306]. Reporting of main group effects for pooled data, solely, has led to incomplete differentiation, detracting from the ability to interpret and apply SSG. Ambiguous and unconventional formulation of comparison between or within conditions, e.g., "(single) effects" and "interaction", further clouds interpretation of the evidence. Commonly used group averages, including HR_{MEAN}, HR_{MAX}, V_{MAX}, V_{PEAK}, and peak g forces, were not consistently reported [87-89, 306, 343]. In contrast, arbitrary units, like zones, and labels, are popular (cf. Table 10 and Table 11) [28, 87, 89, 306]. To this regard, the literature would benefit from adequate framing, contextualisation, systematic investigation, standardised lexicon, and transparent reporting and argumentation.

In addition to more than half of the investigations' statistical analysis falling short of reporting clear and complete practical relevance, power analyses were not reported for any of the studies [87, 88, 149, 338]. This oversight is assumed to be related to the availability-dependency of participants in team sports research. An average amount of 30 ± 12.6 participants was used per study in the available literature, indicating a wide range between studies [14 – 53] [28, 87]. It is worth noting however, that participants were either groups subjected to one or repeated conditions, as a whole [28, 163, 338], or groups from which subjects were selected for specific conditions [87, 88, 149, 339]. This implies, potentially, more or less data points than subjects were collected per condition. Incomplete reporting meant exact participant inclusion could not be confirmed across studies.

Single, double, or triple blinding was not applied across the studies, leaving the literature vulnerable to risk of detection bias. However, no systematic differences were found for any of the investigations in the determination of outcomes between groups. Most outcomes were assessed by automatic measurement, objectifying them. The risk of detection bias was consequently judged as low across the studies.

Performance bias can be caused by factors external, as well as internal to participants. Consequently, attention from investigators or coaching staff towards participants, and knowledge about allocation to conditions should be considered. While allocation concealment did not occur, and is unlikely in practical team sport research settings, it is questionable whether participants were aware of the expected differences in outcomes, with the exclusion of Gamble (2004) [163]. Standardisation of protocol occurred to some extent in all quasi-experimental studies [87, 88, 149, 163, 339], possibly mitigating the effect of external influences. The necessity for minimising coaching and feedback, to an optimal level, was debatable for some studies [28, 163], but unfulfilled in others [87, 149, 338]. Apart from Gamble (2004) [86], it was not clear in the literature if a double role, i.e. investigator-coach, had the potential to increase the risk of performance bias. Further to that, a declaration of (no) conflict of interest was only found for Vaz et al. (2016) and Tee et al. (2016) [28, 87]. Only three out of seven studies explicitly mentioned funding [28, 87, 88].

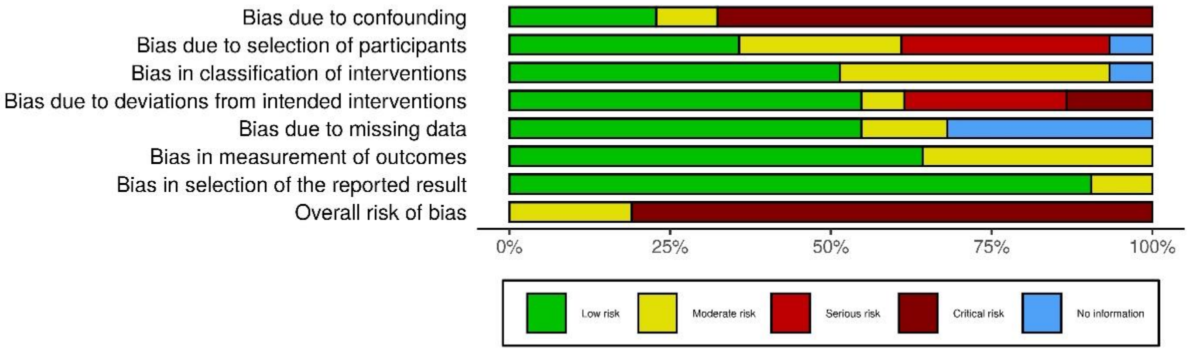

Figure 9 Weighted distribution of RoB within domains across studies

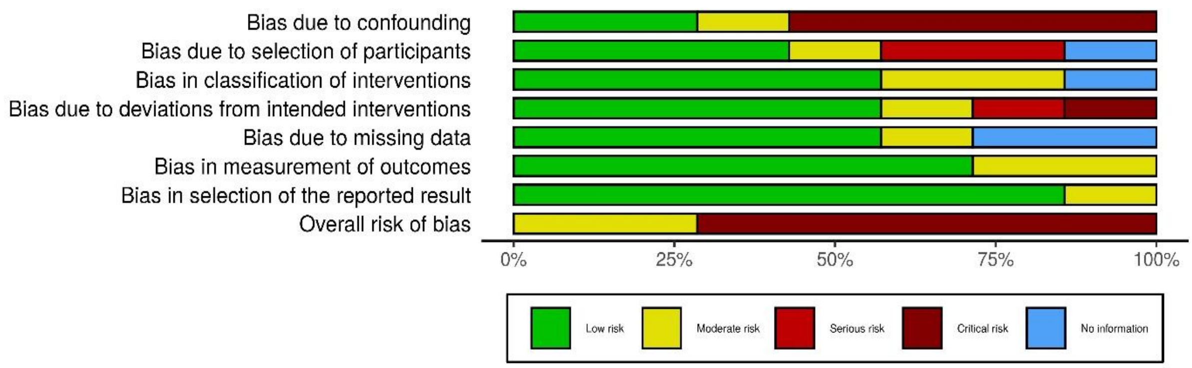

Figure 10 Unweighted distribution of RoB within domains across studies

All publications included statistically significant, as well as non-significant results, with one study concluding no overall effect [343]. These reports of partial and total null result, strengthen the likelihood of there being a limited risk of publication bias. A specific concern across the SSG^{RU} studies remains RoB due to confounding. Managing these prognostic factors, which are established pre-intervention, is an important challenge. Simultaneously, the application and reporting of true randomisation would be most effective at mitigating this risk.

In summary, RoB across the studies mainly relates to issues of rigour and transparency. As a consequence, the original body of knowledge investigated in this study showed a 75% overall RoB, approximately (Figure 9 and Figure 10). Completeness and precision should be applied to experimental design, sampling strategies and selection, allocation procedures, statistical analysis, and the reporting thereof. This detail would elucidate potential biases, clarify possible missing data, and indicate study designs flaws. Overall methodological accuracy, in execution as well as reporting, would benefit sport science research as a whole.

4.3.7 Additional analysis

Table 9 and Table 10 list SSG design variables used in the studies originally included, specific outcome variables reported, and HR_Z as well as V_Z used.

To provide a comprehensive insight into the ongoing evolution of this research topic, seven out of eight eligible studies from ninety-six identified follow-up search results are additionally presented below and chronologically analysed [97, 344-348]. One study was part of this doctoral investigation and will therefore be discussed later [349]. Noteworthy, an additional study on learning the skill of passing in SSG^{RU} was obtained after the original search and prior to the follow-up search via other means [350]. However, this study was not included due to not meeting the fifth eligibility criterium; incorporation of physiologic, kinematic, or physical outcome measures. A study on female players was in turn included, for its informative contribution to the literature [283].

This study from Chadwick and colleagues compared the physical demands of non-contact versus contact SSG and matches in female RU players [283]. Unclear sampling and randomisation were used to recruit fifteen collegiate-level players (19.8 ± 1.6 years, 1.65 ± 0.07 m, 70.5 ± 13.1 kg). These players performed two twenty-minute SSG (two-hand touch vs RU rules) of undisclosed, yet constant player numbers, divided by twenty minutes of active recovery on a 30 x 70 m artificial 3G pitch. A follow-up official BUCS Northern 1a league RU game was played after two weeks. HR and microsensor monitoring (incl. 10Hz GPS) revealed higher RD and lower tackle rate for non-contact SSG compared to both RU match and SSG, and lower player load for non-contact than for match. Average HR and relative time spent in HR_Z and V_Z were similar for all conditions. More than 71% of the time was spent below 85% HR_{MAX} and less than 15% above 90% HR_{MAX}. At least 97% of time qualified as "low-speed movements", with "walking" accounting for approximately half of game time. The speed categories used were adopted form prior research [112]. The authors conclude that both SSG formats can replicate match demands in a relative sense, with non-contact offering the possibility of more conditioning stimuli at lower injury risk.

Taylor and colleagues investigated the reliability and validity of integrated external and internal load ratios as measures of aerobic fitness in English academy RU U18 players during a three-week period (n=12, 17.6 ± 0.44 years, 179.4 ± 6.3 cm, 83.3 ± 9.7 kg) [344]. A test-retest protocol, seven days apart, saw three exercise protocols compared, including SSG (6v6, 10 min, 39x51m, touch rules; 6+ tackle or passing/handling-error turnover). Measures of HR, VO_{2MAX}, lactate threshold (LT), onset of blood lactate accumulation (OBLA), individualised training impulse (iTRIMP), and kinematic data from a microsensor device (incl. 10 Hz GPS) were used. Bayesian pearson's corelations showed large-to-very large associations between specific internal/external load ratios and fitness criterion for all protocols. Coefficients of variation (CV) only demonstrated good reliability for integrated measures in the SSG format (11-12%), alongside sprint interval training (7-11%). Therefore, these training forms were concluded to be most suitable to assess submaximal fitness in this RU sample.

In 2021 Zanin et al. were the first to publish a systematic literature review regarding SSG in the rugby football codes, incorporating rugby league, RU, and rugby 7s[97]. PRISMA and "Synthesis Without Meta-analysis" guidelines were used to investigate acute effects on technical, tactical, and physical outcomes, with internal and external load measures, as well as chronic performance adaptations to such exposures in SSG [304, 351]. Without covering all PRISMA checklist items explicitly or distinctly (e.g., "protocol and registration", "risk of bias assessment within/between studies", or "additional analyses"), clarity and traceability were provided on most systematic search and review elements. From 1261 identified search records, the review structure differentiated between 17 acute studies (13 rugby league + 4 RU) and 3 chronic studies (2 rugby league, 1 RU) [86-88, 149, 343].

Study quality was assessed using Downs and Black's Quality index to be poor on average, scoring 38% to 53% for acute and 41% to 47% for chronic outcome studies [321]. The RU-related literature scored 44% on average, with 13 [87, 149], 14 [88], and 15 [86, 343] out of 32 points showing homogeneously low quality across studies. No RoB assessment was performed on individual study outcomes or the cumulative evidence as indicated by PRISMA guidelines [304]. A myriad of study aims, SSG formats, durations, pitch dimensions, playing rules, playing conditions, and outcome measures were listed across studies. Within these study designs no clear uniformity was established. However, HR monitoring and kinematic measurements are recurring elements. Despite the prevalent use of similar measuring methods, the equipment, the reporting units, and categorisation used are varied. Zanin and colleagues reported the effectiveness of SSG for improving physiological markers in RU players [86]. Scarce and inconclusive evidence was presented outlining larger pitches and less players can cause higher or similar external and internal loading in RU players depending on the design [87, 88]. The role of playing experience was found to be of importance, whereas providing knowledge of performance metrics to RU players during SSG was not ergogenic [149, 343]. The effect of playing rules on technical/tactical characteristics and/or external/internal loads, pitch dimension manipulation on technical/tactical characteristics, and contact form manipulation overall, were found missing from RU investigations according to Zanin and colleagues [97]. The authors concluded the evidence for designing SSG in rugby is scarce, due limited studies focussing on the effects of constraint manipulation and a high degree of heterogeneity in study designs and aims. A targeted and differentiated, yet comprehensive approach was suggested for future research.

The use of SSG to elicit attacking behaviour in professional RU forwards (n=21, 187.0 ± 7.7 cm, 116.00 ± 5.60 kg, 24.60 ± 3.80 years) was investigated by Zanin and colleagues through targeting consistency in tactical, technical, and physical performance markers [345]. Randomisation of sampling and allocation were not disclosed but players were divided into four teams who played the same opponent in one or two concurrent SSG daily, on four days interspersed by forty-eight hours. A methodical study design and shared coach/researcher evidence-informed approach was taken to the development of a 6 v 3 format, on a 17.5 x 15m pitch, for 5 x (2.5:1.25 min) W:R, with adapted touch and on-side rules, and specified coach encouragement and feedback timings [84, 191]. Environmental constraints were also outlined. Video-based notational analysis, HR monitoring, and a global navigation satellite system (10 Hz) revealed that the majority of tactical behaviours (width, length, and ratio normalised approximate entropy), technical characteristics ((un)successful passes, line breaks, rucks, tries), and physical characteristics (TD, HSRD (>61%V_{MAX}) [352], Acc/Dec_{AVG}, V_{MAX}, Stagno's TRIMP) were consistent across SSG bouts, when coach input was controlled for.

Differences were seen, only for arow shape formation, TD (238 – 249 m), and Stagno's TRIMP (553 – 590 AU). In contrast, across days, tactical (SD = 0.03–0.08) and physical markers (e.g., Stagno's TRIMP SD = 34.14, TD SD = 9.33) showed minimal variability, whereas technical characteristics were consistent. Therefore, practically meaningful consistency can be achieved for tactical, technical, and physical outcomes in SSG with RU forwards, based on the measures considered and when controlling for coaching.

In a retrospective cohort study on SSG, GBT (i.e., 15v15, full field), and (aerobic and anaerobic) conditioning training, Peek et al. compared one-to-six-minute rolling peak epochs of movement and impact characteristics in male professional Super Rugby players (n= 42, details undisclosed) [346]. Positional but not anthropometric details were obtained. Data was collected using microsensor devices (incl. 10 Hz GPS) during a twelve-week in-season period. Sixty-three files using 108 unspecified SSG drills were identified, which generally lasted less than six minutes. On average, the one minute-epoch peak movement characteristics in training ranged between 126 $m \cdot min^{-1}$ (conditioning training, outside back) and 225 $m \cdot min^{-1}$ (SSG, outside back). Differences were also evident for position (p = 0.022–0.434) and intensity period (p<0.001) for RD and relative impacts performed across methods, with peak impacts of 1–2 $impacts \cdot min^{-1}$ observed generally. Likewise, a mean squared error of 242.9 underpinned a large variability for movement characteristics between players. Comparatively, SSG elicited the highest RD (up to ~250 $m \cdot min^{-1}$) of all methods. Most of the time was performed at 30–39% (conditioning training and SGG) and 40–49% (GBT) of peak movement intensity and zero $impacts \cdot min^{-1}$. Overall, SSG showed to be superior to GBT and conditioning training in eliciting greater peak movement intensities across all one-to-six-minute periods for each positional group. The authors highlighted that the design of these training methods is of the essence to obtain desired training response.

Zanin and colleagues studied the chronological variability and playing position-related differences in physical and technical characteristics for SSG^{RU} [347]. Eight-teen professional RU backs (182.83 ± 6.05 cm, 95.28 ± 9.61 kg, 26.09 ± 5.32 years) and 22 forwards (187.28 ± 6.83 cm, 114.68 ± 6.25 kg, 23.56 ± 3.60 years) were recruited using availability sampling to participate in separate and joint (forwards-backs) SSG during a three-week pre-season period. Allocation and randomisation practices were not specified, but three well-specified SSG formats included 6 v 3 on 17.5 x 15m for 5 bouts of 2.5 min (2:1), and 11 v 8 on 35 x 30m for 3 x 3.5 min (2.3:1) with differentiated adapted touch rules, tactical targets, encouragement, and feedback. A global navigation satellite system (10 Hz), HR monitoring, and a video-based notational system were used to quantify the outcome.

General and generalised mixed-effects models resulted in maximum likelihood estimates, standard errors, SD, Wald statistics, and profile likelihoods CI demonstrating that the joint SSG format showed greater HSRD (>61% V_{MAX}) than separate formats, when comparing within positions (backs 1.97 vs. 1.32 m·min^{-1}; forwards 1.26 vs. 0.94 m·min^{-1}). More successful passes and line breaks were also seen for joint as compared to the forward-only SSG (9.47 vs. 9.36 passes·min^{-1}; 0.98 vs. 0.6 line breaks·min^{-1}). In contrast, TD, average acceleration-deceleration, relative number of get-ups, and Stagno's TRIMP·min^{-1}, unsuccessful passes, rucks, and tries were higher in the divided SSG. Furthermore, all the physical and technical characteristics showed either a linear increase or decrease, or a quadratic pattern for collection days, except for HSRD in forwards and unsuccessful passes and tries per minute. A potential benefit of applying position-specific SSG to enhance players' exposure to specific physical and technical characteristics is suggested. An additional caveat is made for the influence of adaptation over time to constraints, or the onset of fatigue when repeating SSG.

The same data set of the aforementioned professional RU sample (n= 40, 185.27 ± 6.79 m, 105.95 ± 12.53 kg, 24.70 ± 4.58 years) was used by Zanin and colleagues to establish the contributing external load factors to internal load in SSG[RU 348]. General mixed-effects models were used to show that dependent on the SSG format, Stagno's TRIPMP (521.7 – 641.8 AU) related differently to TD (231.2 – 308.6 m), HSRD (0.9 – 3.76 m·sec^{-1} >61% V_{MAX}), average acceleration/deceleration (0.6 -0.7 m·sec^{-1}), PlayerLoad™ (27.6 -31.4 AU), PlayerLoad™ slow (11.0 – 13.55 AU <2M·M.SEC^{-1}), number of get-ups (0.7 – 1.5), and number of first-man-to-ruck (0.8 – 1.2). A maximum likelihood estimate (-121.9), standard error (29.0), and t Wald statistic (-4.2) demonstrated internal load was different between backs and forwards when they played the same game together. This study confirmed that playing constraints can be used within SSG design to manipulate physical and technical characteristics, which in turn elicit targeted cardiovascular responses in professional RU players.

4.4 Discussion

4.4.1 Summary of evidence

The large array of study characteristics (Table 9), the study results (Table 14), and measures (Table 10), demonstrate a lack of focused line of enquiry into the application of SSG to male RU players. This scattered approach is in line with previous research. A plethora of team sports SSG-related publications, especially focused on soccer, has consequently emerged [46-49, 59-61, 175, 201, 299]. Evidence has accumulated but it remains challenging to establish firm conclusions about the influence of SSG design on physical, physiological, kinematic, and skill-related outcome variables [46, 48, 59, 175, 201, 349, 353, 354]. To our knowledge, at the time of the original investigation, this was the first study to review the application of SSG to RU.

Two initial observational studies examined full RU training sessions incorporating SSG [28, 306]. Total session distance seems to be higher than in match-play (e.g., 5787 ± 1212 m vs. 5050 ± 1636 m) [28]. And professional seniors cover more distance in such session than for adolescent players in representative and typical training sessions (~5787 m vs. ~2208 - 4400 m) [117, 119, 139]. However, considering training duration, GBT intensity is likely lower than in matches, as demonstrated by its RD (e.g., 59 ± 8 vs. 69 ± 8 $m \cdot min^{-1}$) [28]. Such discrepancies between training and match intensities have also been shown in adolescents [117]. In training, most distance was covered walking, whereas high-speed distances were lowest [28].

Time spent in HR_Z could be the best predictor for player classification, over age. Critically, most time during GBT sessions was spent under 75% of HR_{MAX} and time above 90% of HR_{MAX} was minimal [306]. The latter threshold has nevertheless been demonstrated to be a prerequisite for specific conditioning in soccer research: a 4x4 minute protocol with three-minute recovery intervals has been shown to enhance VO_{2MAX} [44, 45, 355]. Conversely, Vaz's observations showed players spent less than ten minutes per session in the highest HR_Z [306]. Thus, as adequate intensity (90-95%HR_{MAX}) was not repeatedly reached for long enough duration (4x4 minutes), it uncertain whether the desired conditioning effect would occur in these SSG^{RU} settings.

The preliminary GBT research indicates an 18% mismatch when classifying U16 and U18 based on age versus performance [306]. The younger performance-based cluster observed by Vaz and colleagues generally showed higher values with regards to distance covered, impacts, and HR [306]. This might indicate that younger players exert more energy in training. Similar differences were noted by Read and colleagues (2017) for match demands between age categories in youth rugby, and senior players [16].

The question remains, however, whether the observed physical and physiological differences seen by Vaz and colleagues are effectively inherent to the respective developmental stages, as argued; especially considering training contents differed between age groups. Notwithstanding, performance might be a useful alternative for age grouping to optimise talent identification and training design [306].

The initial observational evidence further showed GBT is adequate for match preparation in terms of kinematic demands, second only to HIIT. However, SSG training sessions need additional walking and jogging, as they fall short these movement categories. In doing so, GBT could reach relative match intensity (69 ± 8 m·min^{-1}). Tee and colleagues' study protocol detail and methodological rigour provide evidence for positional differences in the specificity of training activities, relative to match-play [28]. Further to that, differences in match demands have also been identified between youth RU cohorts, warranting age and position-specific training [16]. SSG will prepare players better for the some positional match demands over others [28]. Considering the observational evidence shows the demands of rugby can vary significantly between match extremes, age groups, and positions, a differentiated, purpose-orientated, and context-specific SSG session design is essential.

Five early-phase studies pursued a quasi-experimental approach, as randomisation of allocation was lacking, using interventions to measure the chronic [86] and acute effects of SSG [87-89, 343]. Within the acute studies, Kennett, Kempton, & Coutts (2012), Vaz et al. (2016), and Weakley et al. (2019), focussed on measuring conditioning responses, while Vaz et al. (2012) also reported skill-related outcomes. Differences in the formulation of research aims, experimental protocols, and reporting methods have led to multiform outcome measures and conclusions across these studies. Even with similar study designs, i.e., quasi-experimental interventional cross-sectional set-ups, direct comparison between SSG is hampered [87, 88, 149, 339].

Kennett and colleagues found HR values during SSG to be below the 90-95% HR_{MAX} mark, as prescribed for improvements in VO_{2MAX} and other physiological and performance markers [44, 88, 356]. The observed values (~ 87 – 89% HR_{MAX}) are comparable to those in rugby league [357] and other football codes' SSG [45, 203]. These HR were not significantly different across field sizes or player numbers. Said target intensity has been found for select SSG only [45, 358]. Yet most SSG designs appear to elicit below 90% of HR_{MAX}, unless specifically targeted [46, 48]. Aside from SSG design, sport specificity and differences in target population can additionally influence the observed outcomes.

The potential to acutely reach effective conditioning intensity with SSG^{RU} was demonstrated by Vaz and colleagues, and Kennett et al. (2012). In their investigations, the majority of SSG playing time was either spent above 85% to 90% of HR_{MAX}, irrespective of playing experience or SSG format used [87, 88, 338]. Of note is that lower player numbers and larger pitch size were perceived (RPE) increasingly more taxing [88]. Furthermore, 4v4 and a large pitch also caused more physiological stress (blood lactate), than 6v6 and 8v8, or a small pitch [88]. The oldest research by Gamble (2004) showed that, with some standardisation, a longitudinal and varied GBT intervention can significantly chronically improve cardiorespiratory fitness in a professional, elite-level environment [163]. As within the other studies, a low injury incidence is noted.

The kinematic profiles found in the early quasi-experimental research for SSG^{RU} generally show clear a speed-distance relationship: i.e., more distance is covered in lower V_Z. However, GBT formats warrant differentiation; LSGs (e.g., 7v7 and 6v6) disproportionately elicited more walking than SSG (e.g., 1v1 and 2v1), which seems to be irrespective of relative playing area [87]. The greatest sprinting distances were found in the largest game formats (i.e., 7v7 and 6v6) and using medium-to-highest relative playing area (500 and 200 m^2/player, respectively) [87, 149]. Conversely, the lowest sprinting distance was found for the lowest player number (i.e., 1v1), yet without correspond to the lowest relative playing area (450m^2/player) [87]. It is important to note the lack of clarity surrounding statistical significance regarding these difference [87]. More HSR, sprints, and higher V_{PEAK} were found for larger pitch sizes. More HSR and sprints were also seen with lower player numbers [88]. Further analysis is required, as interaction effects between pitch size and player numbers were not reported.

Where no differences in movement profiles were found between experience levels, the preliminary research does suggest experienced players perform better at passing, tackling, try scoring, and avoiding intense contacts [149]. Microsensor monitoring indicates LSG elicit more impacts than SSG but less impacts at high-force [87, 149]. Further, verbal feedback between SSG bouts regarding TD does not seem to influence HR, RPE, or locomotor variables [339]. This notion opposes the current consensus thus far in other team sports, but it is important to note the difference between augmented feedback and encouragement [48, 59].

Overall, this initial evidence underpins SSG^{RU} conditioning potential, rather than guarantying its conditioning effects. Differences in movement patterns and technical skill seem plausible for different RU cohorts and between SSG formats. Yet, clear causal relationships have not been established. Monitoring of targeted goals and measured progression is of the essence. Differentiation in measurements is indicated by this early-phase evidence to detect physical, physiological, and kinematic nuances between SSG formats.

Load management through HR and microsensors is endorsed, though adequate monitoring methodology has not consistently been applied. As a consequence of the observed methodological inconsistencies, meaningful and arguably essential kinematic variables such as V_{AVG}, V_{PEAK}, V_{REL}, and $\%V_{MAX}$ in SSG have barely or not been investigated (Table 10).

In summary of the research studies included in the preliminary body of knowledge, sufficient to good quality is observed. In spite of this, a systemic occurrence of subpar sampling and allocation, and the presence of confounders have led to critical risk of bias throughout the evidence, meaning that for one or more areas of methodological focus, these studies should not be used to extrapolate conclusions. Pervasive inconsistencies in this initial body of research's kinematic, physiological, and physical output reporting regarding target variables, metrics, and classifications, make it challenging to draw strong conclusions across cohorts. As only two of these studies reported the elemental design variables player number and pitch size [87, 88], with one study being at critical risk of bias [87], the body is limited in its ability to provide evidence for SSG design. Furthermore, no attention was thereby given to RU youth.

Recent evolutions in the relevant literature have grown the body of knowledge substantially from seven to fifteen eligible studies. In line with prior studies, new investigations explored the influence of playing rules and SSG design on physical, physiological, and kinematic demands. These studies seem to confirm the initial indications that GBT can reproduce key kinematic and physiological match demands on a relative basis, which makes SSG adequate for conditioning players at lower injury risk [283, 344, 346]. Conditioning games can furthermore be used for assessment of submaximal fitness in RU players by monitoring microsensor integrated load ratios [344]. The design of SSG is thereby of influence on the internal and external loads players are subjected to [348]. By extension, using specific SSG designs might cater to consistent technical and tactical training in professional RU players [345]. These investigations clearly further indicate that cohort and position-specificity can play an important role in GBT.

As in the preliminary body of knowledge, the recent evolution shows a variety of quasi-experimental set-ups in aim of divergent research questions. Consequently, a multitude of measurements and metrics are used to quantify mostly the acute effects of different SSG formats. A rise in the use of more valid and reliable measuring tools has been observed and deliberate SSG format design seems to be more prevalent. However, the current body of knowledge has not converged on an approach to systematically understand the effects of design variables. Systematic review of the literature concurs with our findings that, while various approaches have led to scattered and divergent outcome measures and results, SSG^{RU} studies are scarce and require adequate appraisal [97].

The current state of evidence indicates SSG^{RU} can be used in specific circumstances to condition RU players, but the available knowledge is limited in its ability to establish clear cause and effect regarding constraint manipulation, such as player number, field size, and bout-effect, across various RU cohorts, and especially in youth. The evidence as a whole suggests that higher acute physiological and kinematic loading can be achieved with lower player numbers and on larger pitches. However, other factors like cohort-specificity, playing position, and coaching likely influence SSG^{RU} training outcomes. Therefore, differentiation, standardisation, and training load monitoring seem essential.

The deliberate application of SSG^{RU} thus requires player age, playing level, experience, regulation, timing, coaching, monitoring equipment and methods, periodisation, and training outcome variables to be considered. Reporting of relative speed zones and injury rates are thereby currently missing in the literature. Further in-depth study with a focussed line of investigation and a standardised approach to researching SSG design at greater methodological quality and with attention to bias is warranted, on technical and tactical SSG characteristics, in addition to the physical, and especially in RU youth.

4.5 Conclusion

To the authors' knowledge, at the time of its investigation, this was the first study to outline the state of evidence regarding SSG in male RU players. In line with other team sports, SSG^{RU} research demonstrates a heterogeneous character. The practical application of SSG to RU should be done in a considered manner, accounting for the specific context. Training outcomes are the result of complex interactions between design variables, measures, technologies used, and the targeted players.

Rugby-specific conditioning can be attained but different formats differentially emphasise physiological, kinematic, and physical variables. Small-sided games with larger pitches and less players have generally been reported to be more taxing. In addition, complementary training forms should be used to optimally prepare players for the full range of movement demands in competition. Different RU cohorts demonstrate varying skill-levels in SSG and various SSG formats may elicit different playing behaviours.

The current evidence on SSG^{RU} is rudimentary; the literature lacks structural approach, uniformity, and methodological rigidity. Methodologically sound and high-quality future research should aim to systematically investigate the causal effects between SSG design variables on relevant outcome measures such as $HR_{AVG,}$ relative speed, and injury rates, across all RU strata, with special interest in youth.

We suggest a standardised approach by which the effects of the elemental variables are investigated; i.e., player number and field dimensions, primarily. Additionally, bout-effects in SSG youth have not been investigated. In RU practice, SSG should be applied purposefully, first and foremost aimed at reaching optimal exposure at adequate intensity. Future research should provide clear design recommendations to be used as tools, applied in function of practitioners' specific aims.

4.6 Limitations

The limited number of studies included incurred certain limitations on the systematic review process. Firstly, a meta-analysis was not carried out, as the investigated studies' heterogeneity in design, methodology, and outcomes rendered this technique inapt. A further restriction of the inclusion of the identified evidence, based on RoB or quality rating, was omitted as it might have led to an excessively narrow scope. Consequently, some inferences were carefully drawn from a limited scientific basis of variable methodological quality and incurring some potential bias. The identified RoB and quality should therefore concomitantly form the scope through which the available evidence is interpreted.

Despite the authors' conviction towards using the selected RoB and quality assessment, the quality scales were found lacking for full comprehensive evaluation of reporting methodology and non-differential bias of measurements. ROBINS – I furthermore entails the use of esoteric concepts and terminology. The extrapolation of which to non-clinical domains might be limited in its functionality. In spite its rigour and 'best fit', the authors acknowledge the need for contextually optimised RoB and quality assessment (i.e., team sport-specific) tools in future research.

In this study, GPS sampling rates <10 Hz were considered suboptimal, and therefore not fulfilling the validity and reliability requirements to confidently account for all intricacies of SSG play. The evidence for this is presented in 3.5.4 Global positioning satellite system. The authors do recognise that in certain cases, for specific outcome measures, valid and reliable measurements could have been recorded with lower frequency GPS models. However, limited information about recording protocols does not allow for differentiation to that level.

In addition, measurement units, as outcome metrics for the equipment used (e.g., zones), are far from standardised in sport science research. It is known in the scientific community that "researchers and practitioners have become comfortable using generic classifications… But it is still problematic". Moreover, this is seen as "a significant limitation in performance analysis" and remains unresolved (Dr. Timothy Hartwig, with permission). Therefore, mindfulness is required regarding the nature of the quantities or qualities evaluated in the evaluated studies.

KEY POINTS

- **Point 1:** Small-sided games can be an effective conditioning tool in male RU athletes, but the state of the evidence is scattered and too limited to extrapolate widely applicable and concrete practical recommendations.
- **Point 2**: A disparity of methods, designs, equipment, and measurements are used to quantify and describe SSG in RU. There is room for improvement in methodological quality and a standardised approach would mitigate the risk of bias.
- **Point 3**: Rugby union presents an opportunity for a focussed line of investigation into the design of SSG for youth, to obtain cohort-specific recommendations.

CHAPTER 5

Prevalence and implementation of small-sided games in rugby union practice

Chapter prelude

Thus far, we have established that SSG can play a role of importance in rugby and that initial research has been performed regarding SSG^{RU}, alluding to its *wide-spread use as part of the research rationale*. *Systematic review of the relevant body of literature has identified that scant research exists that offers knowledge regarding the physical, physiological, and kinematic effects of SSG^{RU} design. Despite preliminary evidence of its effectiveness, this body of knowledge does not provide useful information regarding SSG design for youth players. Furthermore, we established that the relevant research lacks methodological uniformity, varies in quality, and is at critical RoB. As a consequence, this evidence needs to be approached with reservation. The current situation presents an opportunity, however, to set up a practically relevant basis for further investigation of SSG^{RU}. Therefore, Chapter 5 will investigate the prevalence in implementation of this training method among RU practitioners.*

5.1 Introduction

Small-sided games (SSG) are modified versions of team sports, or generic alternatives, commended and prescribed for their potential to concurrently enhance physiological, technical, tactical, as well as social qualities in a sport-specific manner [47, 49, 84, 175, 176, 199]. This topic has gained importance in the last two decades as evidenced by the increased research into SSG for general use and in specific sports. Rugby union (RU) however, remains understudied in this research area [48, 49, 59, 61, 156, 175, 176, 359-362].

Researchers in a variety of sports, including basketball, lacrosse, handball, Gaelic football, volleyball, soccer, and RU and league have consistently alluded to the popularity of SSG in training practice. This notion of common practice-based use has in fact generally served as a prelude to the scientific rational for SSG-related studies looking into SSG-aspects [50, 51, 53, 54, 200, 203, 204, 339]. The evidence shows SSG generally improve various fitness, skill, and tactical markers [176, 199]. Yet the quantitative data available is not definitive on all accounts [176], nor do SSG replicate match intensities in all contexts [28]. Incorporating the specific performance context might mitigate the documented discrepancy between training and match demands [28, 117, 171] in the pursuit of planned success [29].

RU is a highly demanding, physical, tactical, and skill-based team sport, which taxes all energy systems and requires a complete and position-specific movement arsenal [22, 26, 104, 105]. Rugby competition is characterised by long-duration games, consisting of repeated intermittent bouts of short-duration high-intensity efforts, interspersed with longer periods at lower intensity [26, 161]. The specific game demands consist of a multitude of activities including running, passing, tackling, mauling, kicking, jumping, and scrummaging[104].

The body of knowledge regarding rugby union SSG (SSG^{RU}) is still in its infancy, with only a limited number of studies focussing on the RU-specific population. Within this specific performance-context, the efficacy of SSG^{RU}, their design and constraint-factors, and the influence of player characteristics and feedback on internal and external loading, have been investigated [28, 86-89, 283, 306, 343, 344]. The scarcity and heterogeneity of these studies severely limits inferences on the RU population regarding SSG. The presupposition of widespread use, as a scientific rationale, is in line with that of other team sports. However, here too, scant evidence of SSG^{RU} prevalence, nor the details of its usage in RU training practice are in fact available [26, 97]. Moreover, Thomas and colleagues (2013) have shown the on-field application of effective game-based training can be more challenging than the literature suggests. The inclusion of these training methods into practitioners' arsenals might not be self-evident. Thomas et al. (2013) suggest anchoring SSG into coaches' education through peer-based support to ensure effective implementation [363].

Despite the potential of SSG-application to specific performance-contexts, and the claims made about SSG' widespread use in RU, the lack of evidence regarding its actual practice-based prevalence and implementation impinge on an evaluation of SSG^{RU} real-world efficacy. Clearly, an evidence-based, effective application of SSG could provide important technical, tactical, and physical benefits, within specific performance-contexts in RU. The purpose of this study was therefore to establish an understanding of the actual current application of these training forms to RU-practice and identifying differentiating factors within its implementation, as well as potential asynchrony from the literature. In so doing, optimisation can be sought for the application of SSG^{RU}, relative to their specific performance-contexts.

5.2 Methods

This study entails descriptive research regarding the prevalence and implementation of SSG within the population of RU practitioners through stratification of the sample (n= 115) into various cohorts. To this end, a questionnaire was developed according to methodological good-practice procedures for the development of surveys (e-survey), provided by Portney and Watkins (2009), as outlined below [364].

5.2.1 Developmental procedure

The delineation of the research question was addressed by drafting six guiding questions to help direct the setup of the investigation (Table 16). These guiding questions were complemented by six hypotheses (Table 17), outlining the expected study outcome(s). The translation to a questionnaire outline was bound to the options available in the Qualtrics Online Survey Software [365]. Portney and Watkins (2009) was consulted regarding the identification and selection process of instruments [364].

Table 16 Guiding questions for formalising research question

1. How widely spread is the use of SSG in RU training practice?
2. What are SSG^{RU} generally used for in RU training practice?
3. How frequently are SSG used in RU training practice?
4. Which SSG^{RU} formats are most popular?
5. What are the specific conditioning goals SSG^{RU} are used for in training practices
6. Is there a relationship between RU coaching characteristics and the interpretation and implementation of SSG^{RU}?

Qualtrics Survey Software was selected for methodological convenience and global reach. The design of the instrument was guided by the Qualtrics software workflow [365]. All preliminary drafts were presented to all co-authors for review and adjustments were made through discussion. Upon consensus, the pilot survey was presented to six peers, i.e., sport science researchers and coaches involved in RU, for testing and revisions. Feedback was incorporated to finalise the e-survey. The final survey consisted of 24 multiple-choice questions, in which click-to-select for pre-formulated absolute or categorical options, drag-and-drop for top-x choice, sliding scale formats for percentages, and “Other” input boxes were provided, adhering to best-practice survey methodology [364]; ease of use (PC/smartphone), visual appeal, duration, and a uniform, yet non-identical ranking (randomisation) of available responses were built in. Multiple replies were possible for selected questions (e.g., top 5). The survey structure aimed at creating flow by first addressing simpler, participant-differentiating information, systematically followed by more topic-specific questions. Informed consent was integrated, and ethical approval was obtained through an institutional ethics committee (HREC(Health)2019#15). The survey concluded with an optional declaration of additional information.

5.2.2 Dispersion

RU coaching staff were selected as the target population, i.e., practitioners involved in delivery of training to RU players. Initial dispersion was done on 07/08/2019, through email lists and social media (Facebook, Twitter, and LinkedIn) available from region coaches and staff involved in RU across a broad range of coaching levels. In addition, RU governing bodies, individual clubs, universities, and schools were randomly targeted via email in New Zealand, Australia, Argentina, South Africa, United Kingdom, mainland Europe, and Japan. These emails were re-distributed six times on a regular basis over the course of one year.

Table 17 Research question hypotheses

1.	SSG are used on every level in RU training practice.
2.	SSG are used for multiple reasons, including match specific conditioning, game skills development and fun experience/ motivation.
3.	SSG are used more frequently with rising playing level.
4.	Mid-range SSG (5v5 – 9v9) are most frequently used.
5.	Match specific aerobic conditioning is the main conditioning goal when applying SSG in RU training practice.
6.	Implementation and interpretation of SSG in RU will be dependent on coaches' characteristics.

5.2.3 Analysis

Qualtrics Online Software was used for data processing. Primary results were reported descriptively based on a selection of outputs; absolute total (participants or choice) counts, and percentages of total survey sample size or relative substrata. Mean ± SD were reported where appropriate. To identify any statistically significant relationships ($p \leq 0.05$), crosstabs were formed, and Pearson's Chi-squared test (Chi^2) was run and reported with degrees of freedom (D_f). Cramér's V Effect Size [ES] was added in complement, for practical interpretation of the results. A 95% confidence interval (CI) was also reported for within category-comparison using the Wilson Score interval. For further analysis, including top one, two, and three sum choice count, and graphical outputs, data were exported to a Microsoft Excel 2016 spreadsheet.

5.3 Results

5.3.1 Definition

The definition put forward to the survey participants in aim of establishing an integral baseline understanding referred to SSG^{RU} *as "Any modified version of the full game of rugby (15 v 15), whereby through alteration of design variables like player number, playing area, time, and rules, a specific training outcome is pursued. The games should still be identifiable as rugby-related (rugby ball, contact, basic plays)."* All but one survey respondent (99%) agreed entirely with this definition, whereas a single coach (1%) elaborated with "constraints based" and "ecological dynamics" upon agreeing.

5.3.2 Sample characteristics

One test case and 115 responses (n= 115) were collected over a twelve-month period. Ninety-five respondents were still actively coaching. Eleven respondents coached on the international level, 7 professionally (e.g., Super Rugby, Pro14), 19 at national level, 34 locally, and 44 coached school teams. Of these staff, 61 participants identified as head coach, 24 as strength and conditioning coaches, 19 as assistant coaches, and 2 sport scientists. Nine identified as "other", including a combination role, director of rugby, and school rugby coach. Mean coaching experience was 4.0 ± 1.2 years. Respondents had predominantly been active in New-Zealand and Europe. A minority had coached in North and South America, Africa, Australia, or Asia. No responses were received from the Pacific islands (PI). One respondent coached on several continents. The sample distributions regarding coaching level and role, experience, location, and age-based target group are reported in Table 18. Seventy-nine respondents coached male rugby union players (69%), whereas five coached female players (4%). The remaining 31 respondents coached both sexes (27%).

Table 18 Distribution of respondents by strata characteristics (n)

Coaching level	**International**	**Professional**	**National**	**Local**	**School**				
	11	7	19	34	44				
Coaching position	**Head coach**	**Assistant**	**S&C**	**Scientist**	**Other**				
	61	19	24	2	9				
Experience (years)	**<1**	**1-3**	**3-5**	**5-10**	**>10**				
	2	16	21	22	54				
Geographic location	**NZ**	**Aus**	**Eur**	**Asia**	**Afr**	**SA**	**NA**	**PI**	**Multiple**
	89	2	13	1	3	1	5	0	1
Age target group	**U6**	**U8**	**U10**	**U12**	**U14**	**U16**	**U18**	**U21**	**Seniors**
	7#	12#	22#	32#	25#	21#	39#	19#	39#

S&C = Strength and Conditioning coach; NZ = New Zealand; Aus = Australia; Eur = Europe; Afr = Africa; SA = South America; NA = North America; PI = Pacific islands; U(x) = Under (age group); # Of total 'choice count' (n=216): multiple categories optional.

5.3.3 SSG prevalence

No statistically significant relationships were found between frequency of SSG implementation in RU and playing level, coach experience, player sex, or geographical location. Nor were any of the player age categories statistically related to SSG frequency. There was however a strong relationship with staff role (Table 19). Eighty-five percent of respondents (n=97) reported using SSG regularly to very often. Only one school-level coach reported to be a non-user; thus, 99% of respondents reported using SSG in RU (Figure 11).

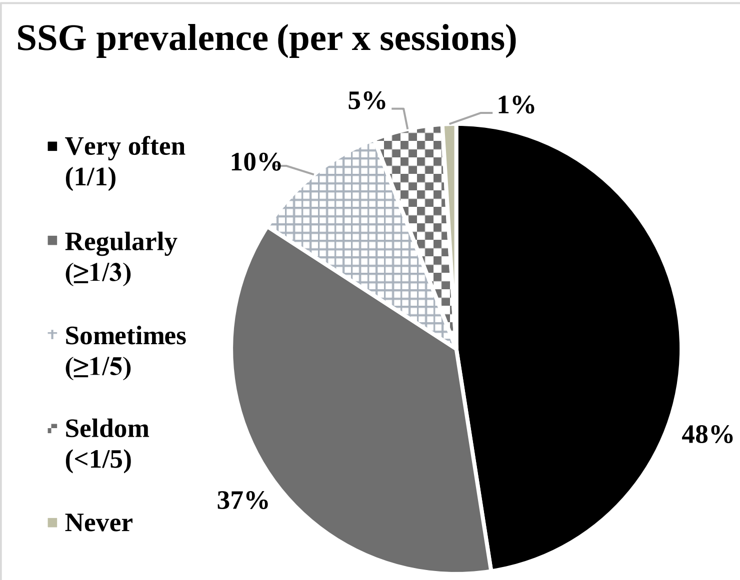

Figure 11 SSG prevalence (% respondents)

Most international coaches (55%) used SSG every two to three sessions. Of the professional coaches, equal amounts (43%) used SSG every session and every two to three sessions. Forty-two and 47% of national-level coaches reported to use SSG every session and every two to three training sessions, respectively. The majority (71%) of locally coaching staff used SSG every session. School rugby coaches in turn, mostly used these training forms every session or every two to three sessions (41%) (Figure 12). With 44% (CI [31-57%]), local-level coaches were significantly overrepresented within the cohort of most frequent SSG users, whereas they were underrepresented with 14% (CI [7-28%]), in regular SSG use ($p \leq 0.01$).

Table 19 Relationship between population sample characteristics and SSG prevalence.

		Chi²	D_f	*p*	[ES]	
Playing level		21.0	16	0.179	0.214	Medium
Coaching experience		21.6	16	0.157	0.217	Medium
Staff role		49.0	16	<0.001*	0.326	Large
Player sex		7.57	8	0.477	0.181	Medium
Geographical location		23.6	28	0.700	0.227	Medium
Player age	**U6**	0.892	4	0.926	0.088	Small
	U8	1.18	4	0.881	0.101	Small
	U10	7.17	4	0.127	0.250	Medium
	U12	1.99	4	0.737	0.132	Small
	U14	5.31	4	0.257	0.215	Medium
	U16	5.10	4	0.277	0.221	Medium
	U18	1.94	4	0.747	0.130	Small
	U21	3.60	4	0.463	0.177	Medium
	Seniors	1.41	4	0.843	0.111	Small

*Statistically significant relationship

Stratification by coaching experience for frequency of SSG implementation shows a practically meaningful ES, demonstrating nuance between categories (Figure 13). Fifty-six percent of coaches with more than ten years of experience applied SSG every session most often. In contrast, inexperienced coaches did not use SSG every session. Rather, they were inclined to a more moderate use. Often and regular SSG use thereafter rises cumulatively, to 83% by ten years of experience.

These most experienced coaches have a statistically ($p \leq 0.01$) lower representation (9% [CI: 2-38%]) for moderate frequency SSG use (≥1/5 sessions), whilst those with 3 to 5 years of experience have significantly higher ($p \leq 0.05$) values than typical within this frequency category (46% [CI: 21-72%]).

Differences are evident between specific staff; 61% [CI: 48-72%] of head coaches applied SSG every single session, which is significantly more than coaches in other roles do ($p \leq 0.01$). Consequently, head coaches form 67% of the total amount of very frequent SSG users. This is compensated by an atypical low proportion of head coaches (28% [CI: 18-40%]) using SSG "regularly" ($p \leq 0.05$). The opposite was observed with 63% of strength and conditioning coaches [CI: 43-79%] implementing SSG at least once per three training sessions, being more than typical ($p \leq 0.01$). However, an atypically low value of 21% [CI: 9-41%] was found for every session-use ($p \leq 0.01$) in this role. Twice 42% of assistant coaches used SSG training "very often" and "regularly" [CI: 23-64%].

SSG formats were applied to all athlete age groups. One to two-thirds of coaches used the games every training session within their respective target age group (Figure 14). Statistically deviating values were only seen in U10 coaches, who demonstrated disproportionately higher values for "seldom", and lower values for "regular" SSG implementation than expected ($p \leq 0.05$). The lowest proportion of very often- users (36%) was found for U14 coaches. SSG use every one to three sessions seemed to fall from U10 to U14 (≤81%), when compared to 83 to 95% of coaches in other age categories. U21 coaches (95%) had the highest proportion of prevalent SSG users. In contrast, U10 and U14 (14% and 12%) coaches were most prone to never or barely apply SSG in training practice.

Practically meaningful distributional differences were noted for SSG implementation to players of different sexes; 91% of respondents who worked with both male and female athletes implemented SSG at least once per three training sessions. In comparison, 84% of the cohort exclusively coaching males, and 60% of those solely coaching females used SSG "very often" or "regularly".

No statistically significant differences were found for SSG prevalence in relation to geographic location. Practically speaking, a prevalence-ranking for SSG application ("very often" and "regular", respectively) was observed for coaches active in Africa (67% and 33%), Europe (54% and 46%), New Zealand (47% and 36%), North America (60% and 20%), and Australia (50% both). One survey participant active on several continents, and one in Asia, reported using SSG every two to three training sessions. Two of four coaches active in Australia, and two in South America declared having used SSG once every five sessions only.

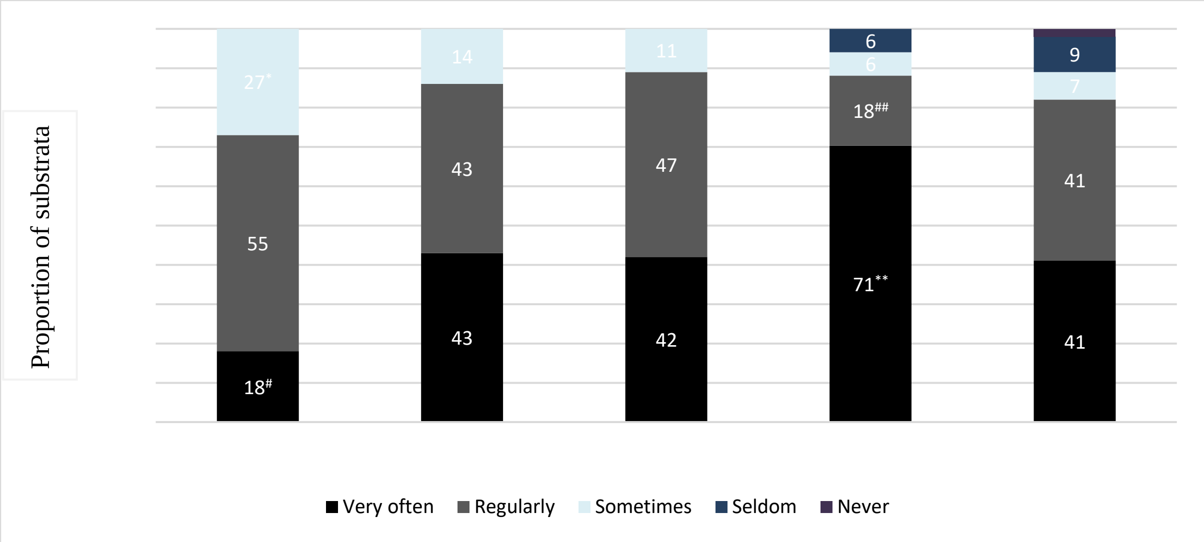

Figure 12 Playing level-dependent SSG use (% of substrata); significantly higher (*/), lower (#/##) than typical ($p \leq 0.05/p \leq 0.01$)**

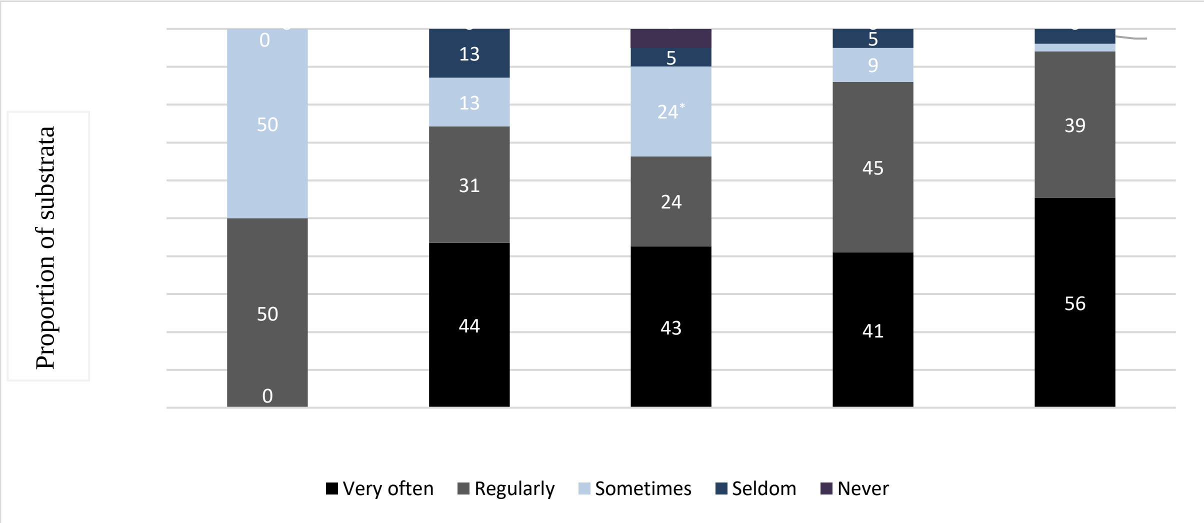

Figure 13 Coaching experience-dependent SSG use; significantly higher (*/), lower (#/##) than typical ($p \leq 0.05/p \leq 0.01$)**

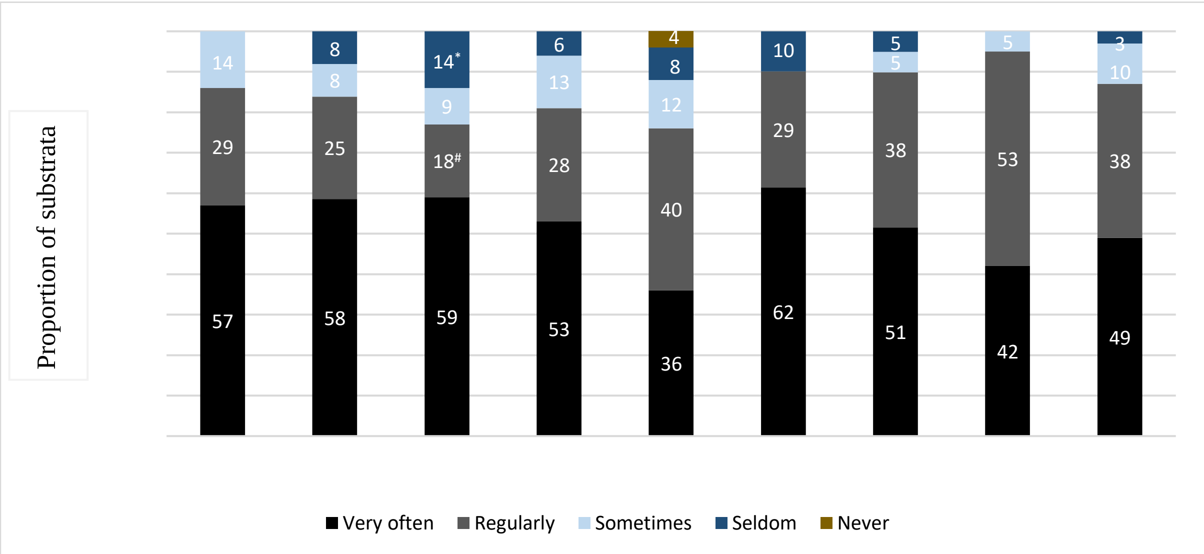

Figure 14 Age group-specific SSG use (% of substrata); significantly higher (*/), lower (#/##) than typical ($p \leq 0.05/p \leq 0.01$)**

5.3.4 SSG Application

The application of game-based training, in general, served multiple purposes according to RU staff (Figure 15). To pursue these aims with a single format, 3 v 3 was elected most frequently. Further in-depth questioning of participants showed 5 v 5, 3 v 3, and 7 v 7, in that order, to be preferred, when allowing for a top-three choice. Skill development, general aerobic and specific match conditioning were identified training goals of SSG. In addition, 1v1 was most preferred in terms of skill development, whilst 10 v 10 was applied almost equally for general aerobic, specific match conditioning, and skill improvement. A detailed view on all game formats is available in Figure 16.

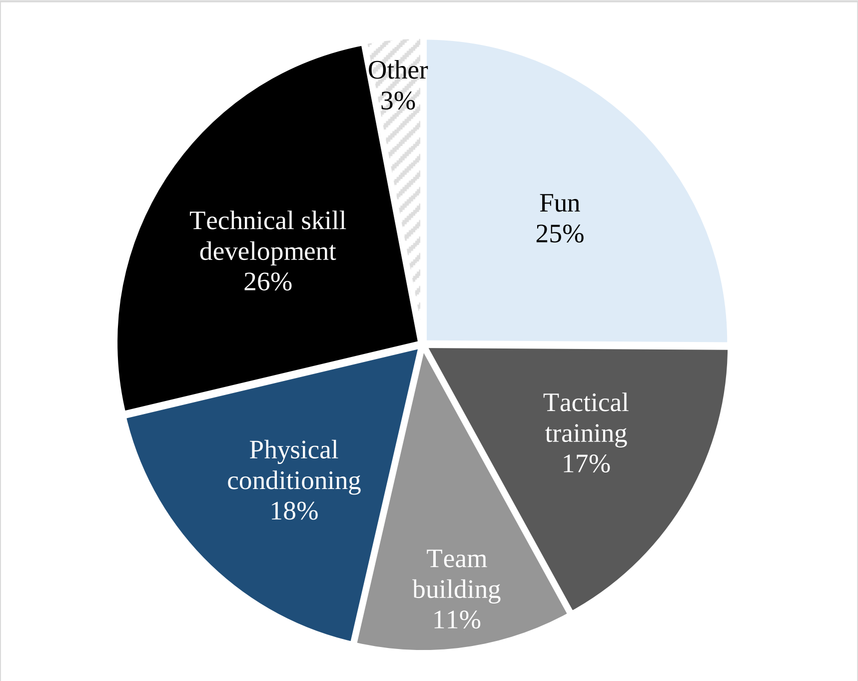

Figure 15 SSG training purpose in RU (% respondents)

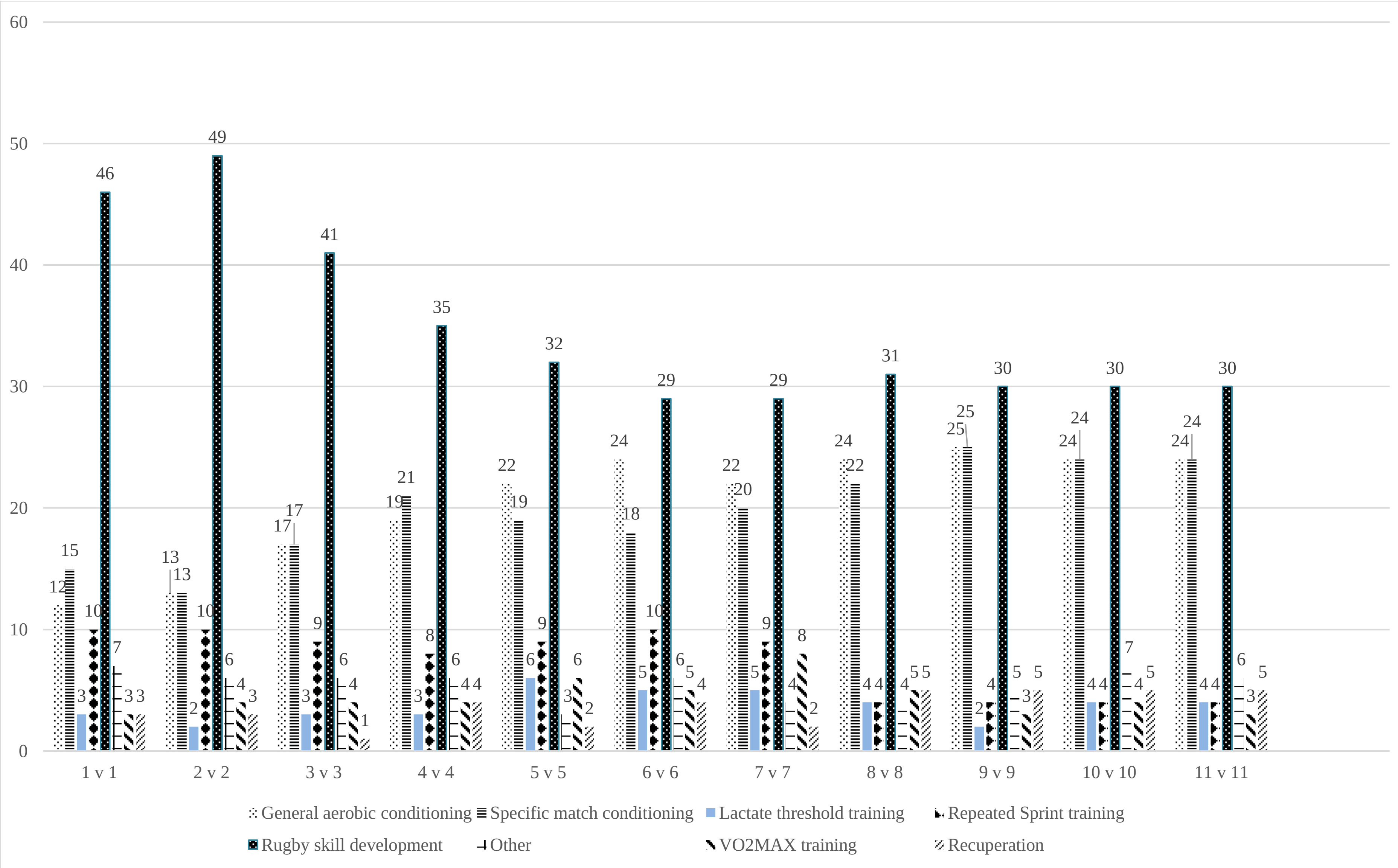

Figure 16 Differentiated training goals for coaches' top five SSG formats preference (% SSG-specific choice)

5.4 Discussion

Although the widespread use of SSG in RU is an accepted notion amongst researchers, with SSG-related research in RU remaining scarce, the evidence for it seems solely grounded in anecdote, at best referencing prior studies with similar statements. This study verifies these claims for the first time and maps out its practical application. The authors put forward, for the first time, a comprehensive RU-specific definition for SSG, which was virtually unanimously ratified by all participants.

Information was collected from coaches representing every level of play. Within the collected sample, school and local coaches accounted for over half the survey responses. This majority exemplifies the truism that more coaches are active on the lower levels of RU, as it is self-evident more amateur than professional players participate throughout societal strata [67]. The survey sample also shows RU staff are active worldwide, in line with RU's global impact [67, 366]. A disproportionate return of survey responses from New Zealand, and in second instance European-based coaches, might reflect geographical differences. This perceived imbalance might be symptomatic of the smaller role RU plays in other parts of the world, relative to other sports [367, 368]. Absolute population, socio-economic factors, and absolute numbers of participation (e.g., Pacific Island nations) could also play a role in the selective survey return. In contrast, when looking at the delivery across targeted age groups, coaching staff were more evenly distributed.

The results show SSG^{RU} are an every-session staple for almost half the respondents. Only a small minority of staff (6%) implemented these training forms infrequently. Despite there being no clear relationship, RU coaches seem to favour the use of SSG increasingly throughout their careers, as experienced coaches implement this method more often than their less experienced counterparts. This observation is consistent with the notion that coaches new to GBT are less proficient in SSG planning and design [176]. A mentorship-approach has consequently been proposed to optimise the integration of game-based training methods in starting coaches [176]. As staff role strongly relates to SSG prevalence, it is of note that head coaches reported the highest amount of every session SSG use (61%). In addition to that, practitioners operating on the local level (71%) also identified as the most frequent users. As such, local-level and head coaches form the largest cohort using SSG most frequently, within their strata of playing level and staff role (44 and 67%, respectively).

The tendency of head coaches to use SSG more frequently could be assumed due to wanting to address various factors simultaneously, more so than other specialised staff, thus selecting a more generalised and game-minded contextual approach. The level-dependency is hypothesised to be due to necessity, favouring potential efficiency, and motivational efficacy with amateur players. Additionally, on the local level, rugby staff specialisation would be less likely. Aside from locally operating coaches, and based on slightly lower frequency (i.e., minimally once per three sessions), SSG prevalence was similar across all levels.

Regardless of player age, SSG were most often implemented every training session. A slight drop in sessional SSG-application with older players might indicate more practice is directed towards compartmentalised and specialised drills. In contrast, ‘fun-experience’ might be emphasised more in youth RU. The higher degree of frequent SSG-usage observed in coaches working with both sexes and males as compared to female players exclusively, is noteworthy. Practically meaningful differences might apply. More evidence is needed to establish potential statistical differences.

Coaches indicated this game-based training methodology is important to them for pursuing technical development and a ‘fun-experience’. Player motivation and enjoyment has been found superior when employing SSG [176]. Greater engagement might consequently lead to better training outcomes. These training outcomes were identified differentially related to specific game formats (Figure 16); the larger the game format, the more it was used for general and match-specific conditioning, whereas smaller game formats were employed for technical development.

In view of the importance of the anaerobic component in rugby performance, practitioners need to consider repeated high-intensity efforts [22, 161]. To that end, coaches used LSG less than SSG to target repeated sprint ability. It is furthermore remarkable that no specific format was reserved for recovery purposes. In general, the variety of SSG^{RU} formats implemented seems to centre around 3-, 5-, and 7-a-side, complemented by individual settings (1 v 1) and large-sided games (LSG) (10 v 10). The data cumulatively shows certain trends exist in training practice, and indicate that among RU coaches, SSG are perceived as multi-purposeful, in accordance with the literature [45, 47, 61, 84, 175, 176, 181, 183, 196, 199, 201, 369, 370]. Increases in technical skill and fun seem hereby to be targeted.

This survey identified a wide range of participants. The collected demographics allow for the classification into a variety of substrata, within which specific emphasis exist for SSG implementation. Experienced New Zealand-based head coaches were the most prevalent. Game-based training was predominantly used to improve technical skill and fun while applied most commonly with (young) adult male RU players.

This study provides evidence indicating that SSG^{RU} are used frequently in New Zealand and likely in Europe. The results show game-based training is prevalent throughout the developmental pathway, on all levels of play. Therefore, we can affirm the plausible and frequent claims in the football codes literature, that to date have been anecdotal and empirically practice-based, yet scientifically unsubstantiated [87, 203, 204, 295, 371-373]. Considering the surge in research regarding SSG in the football codes [48, 59, 175, 199, 201, 374], a factual perspective on practice-based SSG^{RU} usage is indispensable. To our knowledge, this survey is the first to quantify SSG prevalence in RU.

5.5 Conclusion

This study identified the use of SSG by rugby union practitioners. To the authors' knowledge, this is the first survey investigating the application of SSG in rugby union training practice. All rugby union staff agreed with the proposed definition of SSG and provided evidence of its use. SSG are prevalent throughout age groups and playing levels in New Zealand RU. The use of SSG with various target groups is differentiated by practitioners' characteristics. SSG implementation is dependent on staff role and practically meaningful differences might exist for playing levels, coaching experience, player sex, and geographic location, head coaches and coaches in local competitions implement SSG most frequently. Skill enhancement and enjoyment are important reasons for which coaches apply SSG, which commonly incorporate between three to seven players a side. To optimise RU training, a larger body of evidence is required for establishing a more definitive evidence-based perspective on the existing differences in SSG application.

5.6 Limitations

Despite extensive exposure through several electronic platforms, the total amount of completed surveys received was limited for its reach. A disproportionate return of survey responses from New Zealand, and in second instance Europe, means conclusions should only be generalised to those geographic cohorts. Certain limited strata might not fully represent their cohort, aside from geographical location; experience, role, target group, or playing level. The relative weight of these minorities should be considered when interpreting the results, for making inferences and extrapolation.

KEY POINTS

- **Point 1** – RU coaches interpret SSG similarly, adhering to RU specificity.
- **Point 2** – SSG are used across all levels of play and age groups in RU practice.
- **Point 3** – Skill and fun are important drivers and differences in SSG implementation are cohort-dependent.

CHAPTER 6

Design of small-sided games in rugby union: a practice-informed perspective

Chapter prelude

The importance of SSG training in rugby and the limitations of the preliminary body of knowledge identified the need for a focussed line of investigation regarding SSG^{RU}, especially in youth players. In aim of forming a practically relevant basis for our investigation, we examined the prevalence and implementation of these training forms. We were able to confirm that these training forms are very relevant in RU practice, across all levels of play and age groups. Considering the initial indications of differentiation between strata in the RU population and the aim of this doctoral study of SSG application to RU, Chapter 6 will further investigate their design in RU practice.

6.1 Introduction

Game-based training (GBT) is prevalent in team sports [46] , This method is adopted for improving tactical awareness and decision-making, promoting socio-affective qualities, developing physical fitness, and technical skill [47, 96, 175, 176, 199]. These reported benefits are underpinned by scientific rationale [84, 181, 183]. Small-sided games' (SSG) modified and 'downsized' nature makes them practically and logistically useful in team sport settings. The training framework, including the coach's role, design elements such as task constraints, player number, and pitch size, play a determining role in ascertaining beneficial outcomes [84, 175, 176].

Lauded for contextualising training, and thus their potential to simultaneously enhance all performance qualities in a team sport-specific manner [47, 49, 84, 175, 176, 199], the research interest in SSG has surged [46, 58, 61, 84, 85, 200]. Notwithstanding, the dynamics between and the degree to which SSG design variables can positively affect performance qualities are not fully understood. The methodological quality by which these outcomes are measured is debatable, [47-49, 96, 175, 176]. A soccer-centric plethora of SSG research has emerged in the football codes [46-49, 59, 96, 97, 156, 175, 201-204]. In contrast, the relationship between SSG-design and performance outcomes in rugby union (RU) understudied[96, 97].

Rugby training and SSG do not automatically meet RU match demands [28, 117, 171]. Yet, Gamble (2004) provided the first evidence of effective physical conditioning through rugby union SSG (SSG^{RU}), by lowering players' shuttle run-tested maximal heart rate (HR_{MAX}) and improving HR recovery scores, [86]. Different SSG^{RU} designs can meaningfully affect physical performances and skill qualities, despite eliciting similar physiological responses like heart rate (HR), in youth and adults [87, 173]. Larger pitch sizes and less players seem to elicit higher blood lactate levels, RPE, and kinematic responses, but not HR [88].

In contrast to the effects of larger pitch sizes, providing augmented feedback does not seem to produce ergogenic responses in university RU players [343]. Emerging evidence suggests that modifying SSG^{RU}-rules might mitigate injury risk [283]. Training performance during SSG^{RU} might vary despite age grouping, and differences in performance indicators exist for different experience levels, despite similar physical exertion [89, 306]. Using microsensor technology with Integrated load ratios was demonstrated to be reliable for SSG^{RU} monitoring [344].

GBT is implemented broadly by RU practitioners in New Zealand (NZ), Europe, and plausibly other geographical regions. A convergent conceptual understanding of SSG^{RU} exists among practitioners. Three, five, and seven players-a-side were established to be the most popular formats applied. Technical skill and fun are most targeted by practitioners [349]. Fun and playing with friends are the main drivers for RU youth [173]. SSG application might not be uniform throughout RU practice [354].

Implementing GBT, especially at a junior level, is complex; due to its “messy” pedagogical nature, coupling aims and expectations to players’ developmental needs using SSG can be challenging for inexperienced coaches and requires education and peer-based support [363]. Parallel to general SSG research, SSG^{RU} studies display a disparity of essential design elements like player number, pitch sizes, and duration, as well as the choice of target (sub)population. A focussed line of investigation is lacking, and clear rationales are generally not provided. Practical, logistical, or anecdotal factors might be at play. The paucity of research and design-inconsistencies limit the ability to extrapolate guidelines for optimising RU training.

It is important to incorporate the specific performance context in a structured approach towards success. Especially, considering differentiating factors play a determining role in obtaining useful training adaptations [29, 96, 205]. The need for contextual information regarding practice-based SSG-implementation is evident [61].This investigation aimed to provide a differentiating perspective on the contemporary design and practical application of SSG across RU performance and age-group levels, alongside possible disparities between research and practice.

6.2 Methods

6.2.1 Participants

This descriptive investigation targeted the RU coaching population; practitioners with current or prior involvement in training RU players (n= 115). Subject stratification according to characteristics was as follows: 61 head coaches (HC), 24 strength and conditioning coaches (S&C), 19 assistant coaches (AC), 2 sport scientists, 9 "other" e.g., "director of rugby", "school rugby coach". Coaching experience: 2 [< 1 year], 16 [1 – 3 years], 21 [3 – 5 years], 22 [5 – 10 years], and 54 [> 10 years]. Mean experience 4.0 ± 1.2 years. Geographical location: NZ (89), Europe (13), North America (5), Africa (3), Australia (2), Asia (1), South America (1), multiple countries/continents (1). Table 20 summarises the characteristic of the survey respondents' target groups.

6.2.2 e-Survey

The electronic survey was developed systematically (Appendix 8: Survey workflow process) ; delineation of the research question through guiding questions, questionnaire outlining, response hypotheses, review of available instruments, preliminary drafts, and internal and external pilot testing [364]. Qualtrics Online Survey Software was used. The final version incorporated twenty-four questions taking approximately ten minutes to complete. Best-practice methodological response modes were incorporated for maximal return; multiple-choice, sliding scales, and drag-and-drop. Multiple picks, "Other" options, and an unstructured additional information box were included. A Structured, yet randomised order of reply options was incorporated for multiple-choice selections.

A cover letter accompanied the survey to inform prospective participants, in addition to the built-in informed consent at the start of the e-survey [364]. For global reach, the survey was dispersed via email listings and the social media platforms of Facebook, Twitter, and LinkedIn. Rugby union governing bodies, staff, and clubs, as well as universities and schools were systematically and randomly targeted in NZ, Australia, Argentina, South Africa, United Kingdom, mainland Europe, and Japan. This process was repeated six times in the following year. The workflow process and survey questions is available in Appendix 9: Survey content. Ethical approval was obtained through the University of Waikato Human Research Ethics Committee (HREC(Health)2019#15).

6.2.3 Statistical analysis

Qualtrics Online Software was used for processing and managing the collected data to obtain meaningful results with selected variables and metrics. Statistically significant relationships ($p \leq 0.05$) between categorical variables were established through crosstabs with Chi-squared test (Chi^2). For practical interpretation of the results Cramér's V or Cohen's f Effect Size [ES] was added in complement as "trivial", "small", "medium", or "large", depending on the variables considered and their number of groups. For further clarification of results and graphical outputs a Microsoft Word and Excel 2016 spreadsheet were used. Results were reported as absolute total (participants or choice) counts, and percentages (%) of total survey respondents (n=115), or relative to their cohort. Mean ± SD were reported for selected outcomes.

Table 20 Study subjects' target groups (n)

Age	**U6**	**U8**	**U10**	**U12**	**U14**	**U16**	**U18**	**U21**	**Seniors**
	3	6	10	15	12	10	18	9	18
Level	**International**		**Professional**		**National**		**Local**		**School**
	11		7		19		34		44
Sex	**Male**			**Female**			**Both**		
	79			5			31		

6.3 Results

6.3.1 Training objective

Technical skill (26%), fun (25%), physical conditioning (18%), tactical training (17%), team building (11%), and other (3%) were reasons for applying SSG. A goal-oriented practitioners' perspective on SSG application, stratified for playing level and target age group are reported in Figure 17and Figure 18 Significant correlations and a large ES were found between playing level and physical conditioning (Chi^2= 19.8; p≤0.001), other (Chi^2= 12.5; p≤0.01), and team building (Chi^2= 10.8; p≤0.05). A trend to significance and medium ES was seen for playing level and fun (Chi^2= 8.4; p≤0.08). Small ES were found with tactical and technical skill development.

Figure 17 Level-dependent SSG training goal (% of substrata)

A significant relationship with large ES was also seen between practitioners' roles and SSG application for physical conditioning (Chi^2= 21.7; p≤0.001), team building (Chi^2= 11.2; p≤0.05), and fun (Chi^2= 9.8; p≤0.05). A medium ES with no significance was found for other SSG goals, and a small ES with tactical training, relating to practitioners' roles. Head and AC targeted fun (26% and 28% respectively) and technical skill development (25% and 30%) during SSG^{RU}, more than tactics (17% and 18%) and conditioning (15% and 10%). S&C focussed more on physical conditioning (31%), before fun (24%) and technique (23%). Team sport scientists sought fun, technical, and tactical training, and physical conditioning evenly (25%).

Differentiation by coaching experience revealed a significant relationship (Chi^2= 10.7; $p \le 0.05$) with a large ES for tactical goals only; more of lesser-experienced practitioners (1-3 years) pursued tactical GBT than more experienced practitioners (20% vs 9-13%). Nevertheless, a medium ES was detected for team building, and a small ES for physical conditioning, technical skill, fun, and other goals. Fun and technical skills remained the main drivers throughout the practitioners' pathway.

Player sex correlated with tactical training (Chi^2= 6.5) and teambuilding (Chi^2= 6.4) ($p \le 0.05$), with a medium ES. All other SSG goals showed small ES. Practitioners working with female players and male players respectively, both prioritised fun (33% and 26%) and skill (33% and 25%) in their SSG training. In 20% of cases, practitioners delivered SSG to male players for physical conditioning, identical to that for female players. Conversely, practitioners coaching female players did not consider tactical training as an objective, where this was the case in 17% for male players.

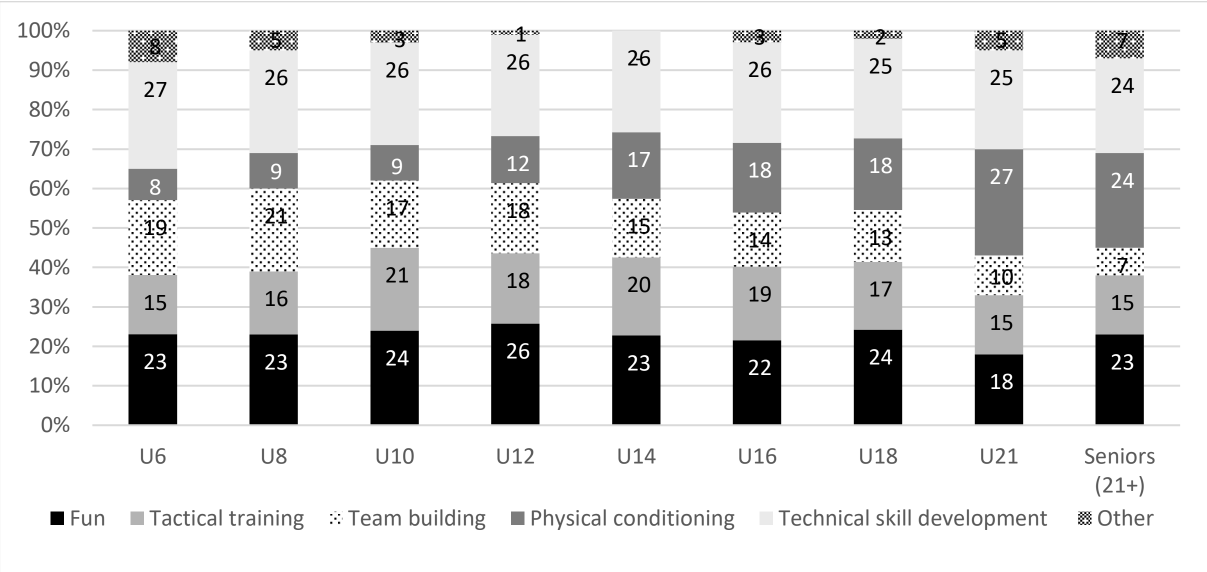

Figure 18 Age group-dependent SSG training goal (% of substrata)

Fun and development of technical skill were targeted by 24% to 29% and 25% to 26% of respondents, respectively, regardless of frequency. Practitioners who seldom (<1/5) used SSG, targeted physical conditioning in 13% of cases, in contrasts to 21% and 23% of regular (≥1/3) or moderate (≥1/5) SSG users. Yet, very regular (1/1) users pursued physical conditioning in 14% of cases. Tactical SSG were applied incrementally more by practitioners who used GBT more often [6% - 19%]. Conversely, team building was pursued by a larger fractions of practitioners seldomly applying GBT (25%), as opposed to those using games more regularly [9-13%].

No significant correlations were found between frequency and training goals, despite medium ES with physical conditioning, tactical training, team building, and fun on the one hand, and small ES with technical skill and other goals on the other.

“Rugby skill development” was the main target overall [29-49%], specifically for practitioners’ reported top five SSG-formats (1 to 11-a-side). Both “general aerobic” [12-25%] and “specific match conditioning” [13-25%] were secondary goals. The results showed 1v1 – 4v4 were used by more practitioners [35-49%] for “rugby skill development”, and 4v4 – 11v11 were prominent for conditioning [19-25%]. No single format was applied widely, nor disproportionally favoured for recovery [1-5%]. SSG were often used by some practitioners as an add-on from closed skill learning; a skill learnt in isolation was thereby put into practice.

6.3.2 Format

Table 21 provides a differential view on coaches’ most popular game formats; a top-three ranking, based on respondents’ top-five out of eleven available SSG formats. This is, the formats chosen first, second, and third most often, within a top one, three, and five cumulation, e.g., 3v3 was the first-most prevalent format when looking at first picks, and the second-most prevalent format within respondents’ top three choices.

Table 21 Rugby union coach SSG-format sum choice count

	Choice Limit		
Ranking	**TOP 1**	**TOP 3**	**TOP 5**
1	3 v 3	5 v 5	5 v 5
2	7 v 7	3 v 3	10 v 10
3	11 v 11	7 v 7	1 v 1

The top-five choice count on the international level, revealed 5v5 was a distinct first pick format (45%) to be applied in training. On the professional level, 8v8, 10v10, and 11v11 tied as a first choice (29%). National practitioners prioritised 7v7 firstly (37%), whereas 3v3 was preferred on the local (26%) and school level (34%). 9v9 was a popular second choice within the top-five picks for internationals (27%), as were 8v8 and 10v10 for professionals (29% each). No further marked distinctions were noted on other playing levels. 1v1 consistently ranked fifth (top-five form eleven formats) for professional (43%), national (42%), and school practitioners (23%) alike, where 1v1 was second (18%) only to 10v10 (24%) on the local level. The latter was also a popular fifth pick on the school level (18%). No international practitioners chose 1v1 as a fifth choice, however. Table 22 reports the likeliness of application for specific SSG formats in relation to coaching experience.

Table 22 Coaches' SSG-format preference, relative to experience (% of responses within substrata)

	Coaching experience				
Choice	**< 1y**	**1-3y**	**3-5y**	**5-10y**	**>10y**
1st	3v3/5v5 (50%)	3v3/11v11 (25%)	7v7 (24%)	7v7 (23%)	3v3 (20%)
2nd	2v2/4v4 (50%)	5v5 (31%)	2v2 (19%)	3v3/5v5 (18%)	8v8 (17%)
3rd	3v3/11v11 (50%)	10v10 (25%)	4v4 (24%)	5v5 (27%)	7v7 (20%)

From U6 to U18, 3 v 3 was markedly preferred as the single applied SSG-format of choice (28% - 52%), only second to 7 v 7 for U14 (28% vs. 32%). 1 v 1 was thereby also distinctly frequently chosen for U6 (29%) and U8 (25%). In contrast to this youth range trend, no SSG^{RU} format was clearly preferred in the U18 to 21+ age-range; a variety of one, three, five, seven, ten, and eleven players-a-side were mainly implemented.

Most of NZ practitioners prioritised 3 v 3 (27%) over 7 v 7 (18%) and 11 v 11 (15%). In Europe, 7 v 7 was a first choice-format for more practitioners (31%), than 5 v 5 and 8 v 8 (15% both). A clear distinction was furthermore seen between functions; 30% of HC' first choice went towards 3 v 3, where 33% of S&C and 26% of AC preferred 7 v 7. For female athletes, 5 v 5 and 7 v 7 (both 40%), and male athletes, 3 v 3 (22%) and 7 v 7 (20%) were the coaches' first choice most often. 23% of respondents coaching both sexes applied 3 v 3 and 11 v 11 more readily.

6.3.3 Field dimensions

Small, medium, and large pitch size was defined by the study participants on a sliding scale as respectively being 33 ± 22%, 45 ± 16%, and 65 ± 28% of a full-sized rugby field. Interpretation of field size varied per playing level, despite small ES and no statistical significance detected; the largest discrepancies exist for small pitch area between international coaches (26 ± 9%) and local or school coaches (34 ± 21% and 34 ± 25%, respectively), local (42 ± 17%) and international coaches (48 ± 8%) for medium pitches, and school or local coaches (61 ± 29% and 61 ± 30%, respectively) versus international coaches (80 ± 19%) for large pitches. Practitioners' roles showed a small ES for medium pitch size only, and trivial or no effects for other sizes. Team sport scientists and S&C respectively reported more extreme dimensions for large (75 ± 5% and 73 ± 23%) and small (23 ± 8% and 27 ± 12%) pitches, compared to other practitioners. A target age group-specific interpretation of field dimensions is available in Table 23.

Table 23 Coaches' perception of relative SSGRU pitch size area by age -group (mean ± SD of substrata)

		Pitch size (% full pitch)		
Age group	**n**	**small**	**medium**	**large**
U6	3	47 ± 28	50 ± 25	64 ± 34
U8	6	47 ± 29	46 ± 21	55 ± 32
U10	10	33 ± 22	44 ± 19	62 ± 29
U12	15	35 ± 22	46 ± 19	64 ± 28
U14	12	43 ± 27	49 ± 22	56 ± 25
U16	10	35 ± 25	45 ± 19	64 ± 23
U18	18	27 ± 21	45 ± 18	68 ± 25
U21	9	23 ± 11	43 ± 14	71 ± 22
21+	18	31 ± 18	48 ± 11	78 ± 24

6.3.4 Duration

Most SSG had a reported duration of between two and ten minutes (Figure 19). Nearly half of the respondents (47%) chose three consecutive SSG bouts, as opposed to 30% of practitioners opting for two bouts, and 14% for four bouts. Just 3% of practitioners preferred one single bout, whilst 7% implement five or more bouts. Half of the respondents (50%) implemented two-to-four-minute rests between playing bouts, while a third of respondents (34%) preferred less than two minutes. A minority chose four-to-six-minute rests (11%), or longer (4%).

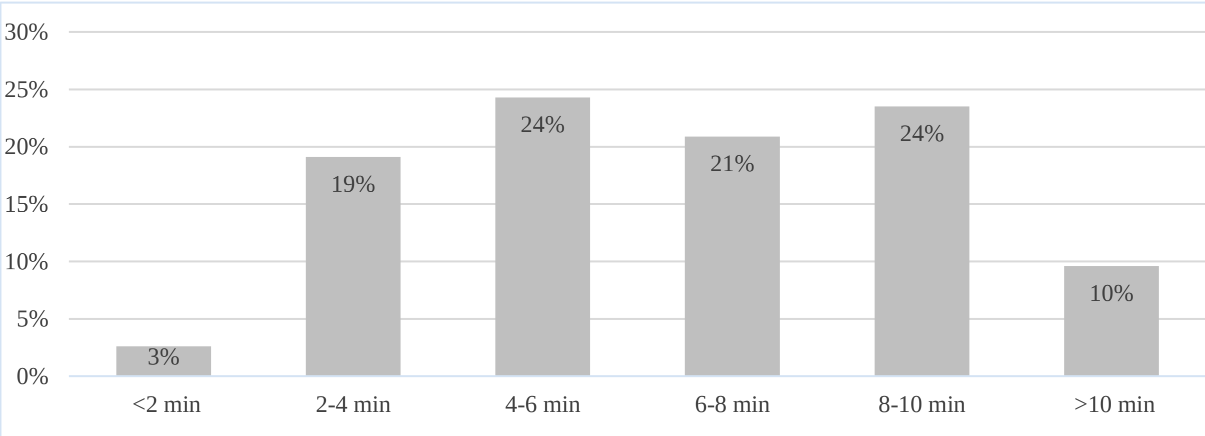

Figure 19 Preferred SSG duration (% respondents)

Stratification reveals clear differences in SSG bout timing for playing levels (Chi^2=32.6; $p \leq 0.05$; medium ES); (semi-)professionals contrast amateurs markedly (Figure 20). A significant relationship with a large ES was also detected between SSG bout duration and some age groups; seniors and U21 (Chi^2= 11.4 and 13.7; $p \leq 0.05$) (Figure 21). In contrast, U10 - U14 and U18 showed medium ES, while U6, U8, and U16 showed small ES. Consequently, SSG duration in adults generally contrast that in youth.

Respondents with various coaching experience showed a mixed variety of mid-range duration preferences ($p \geq 0.05$; medium ES). However, all practitioners with under one year-experience opted for eight to ten-minute SSG. Table 24 shows the relationship between SSG duration and training objectives.

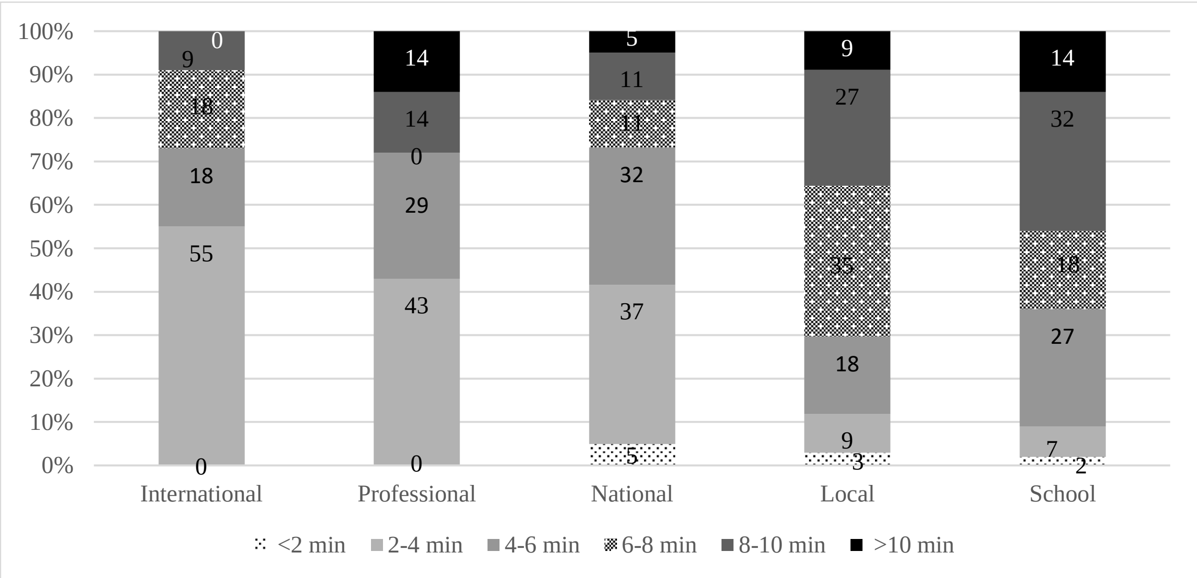

Figure 20 Playing level-specific SSG bout duration (% of substrata)

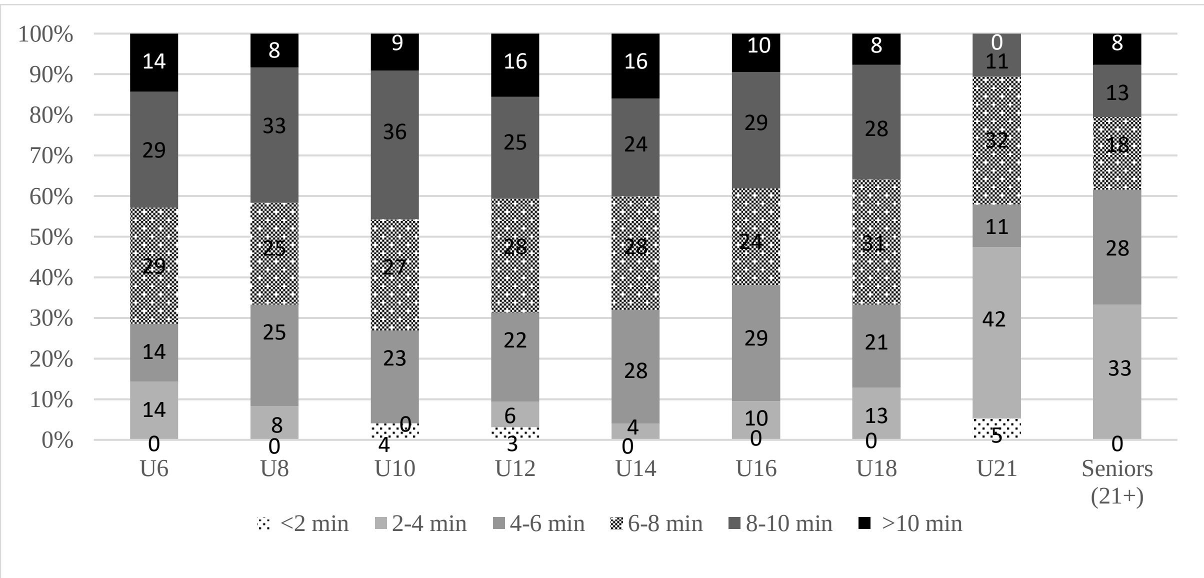

Figure 21 Age category-specific SSG bout duration (% of substrata)

Table 24 % of data points in both groups (for a maximum of three multiple choice training objectives)

SSG duration	**Training objective**					
Min	Technical skill	Team building	Fun	Physical conditioning	Tactical training	Other
<2	2.6	0.9	1.7	1.7	0.9	0.0
2-4	13.9	4.3	13.9	13.0	9.6	2.6
4-6	15.7	8.7	19.1	12.2	13.0	4.3
6-8	17.4	7.8	15.7	10.4	11.3	1.7
8-10	22.6	9.6	22.6	12.2	11.3	0.0
>10	8.7	5.2	6.1	6.1	7.0	0.9

6.3.5 Constraints

Most practitioners prioritise tackling[1] (37%) and touch[2] (36%) RU rules, over "wrapping"[3] (28%) during SSG play. Clear differences were found between levels of play, and for age categories (Figure 22 and Figure 23); tackling was absent in SSG play at the higher playing levels but was prominent in lower level and youth rugby. The relationship between playing level and contact rules implemented was statistically significant (Chi^2=20.5; $p \leq 0.01$; large ES), as with age categories Seniors (Chi^2=21.2; $p \leq 0.0001$; large ES), U10 (Chi^2=12.2), U12 (Chi^2=10.5), and U21 (Chi^2=9.1) ($p \leq 0.01$; medium ES), and U8 (Chi^2=7.1 $p \leq 0.05$; medium ES). Other age categories showed non-significant small ES. Sex-related differences were also noted, as coaches of male players preferred tackling or touch (both 35%) to wrapping (29%), whereas those coaching females only utilised wrapping (80%) and touch (20%). Practitioners delivering SSG to both genders primarily implemented tackling (45%), before touch (39%) and wrapping (16%). Player sex correlated to tackling rules implemented (Chi^2=9.4; p=0.05; small ES).

Stratification by coaching experience showed a medium ES in relation to rules (Chi^2=8.8; $p \geq 0.05$): practitioners with three to five years implemented union rules most commonly in SSG (52%), more so than touch (33%) or wrapping (14%). These choices contrasted with novice practitioners (< 1 year), who opted for touch and wrapping (50% both). Highly experienced practitioners (>10 years) used union (35%), touch (30%), and wrapping rules (35%) relatively evenly.

[1] Bringing the ball carrier to the ground to contest the ball, i.e., full rugby rules.
[2] Touching the ball carrier with one or both hands to contest the ball.
[3] Wrapping one's arms around the ball carrier to contest the ball.

A large ES further indicated a strong correlation between practitioner role and rules implemented: AC and HC were proportionally more likely to use tackling (53% and 46%, respectively) than S&C coaches (4%) (Chi^2=25.9; $p \leq 0.001$). Furthermore, there is a statistically significant relationship between geographic location and contact rules implemented (Chi^2=25.8; $p \leq 0.05$; large ES): NZ-based practitioners applied union rules to SSG, over touch and wrapping (45%, 34%, and 21%, respectively), as opposed to European-based practitioners (8%, 38%, and 54%, respectively).

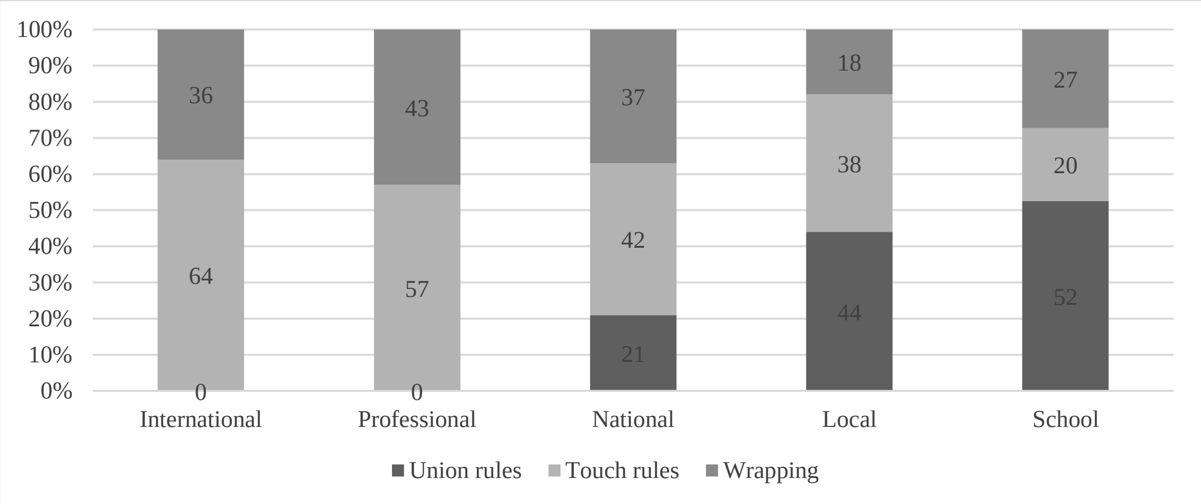

Figure 22. Level-specific SSG-playing rule preference (% of substrata)

Most practitioners chose four (16%), five (23%), and six (28%) "touches" before a turnover, opting to facilitate medium-length plays. 73% of respondents only allowed backwards passing. Uneven teams (1), defenders down/up on touch (2), and man on marking (3) were the most popular additional rules implemented. Table 25 shows a differential of specific playing rules applied in function of targeted training goals.

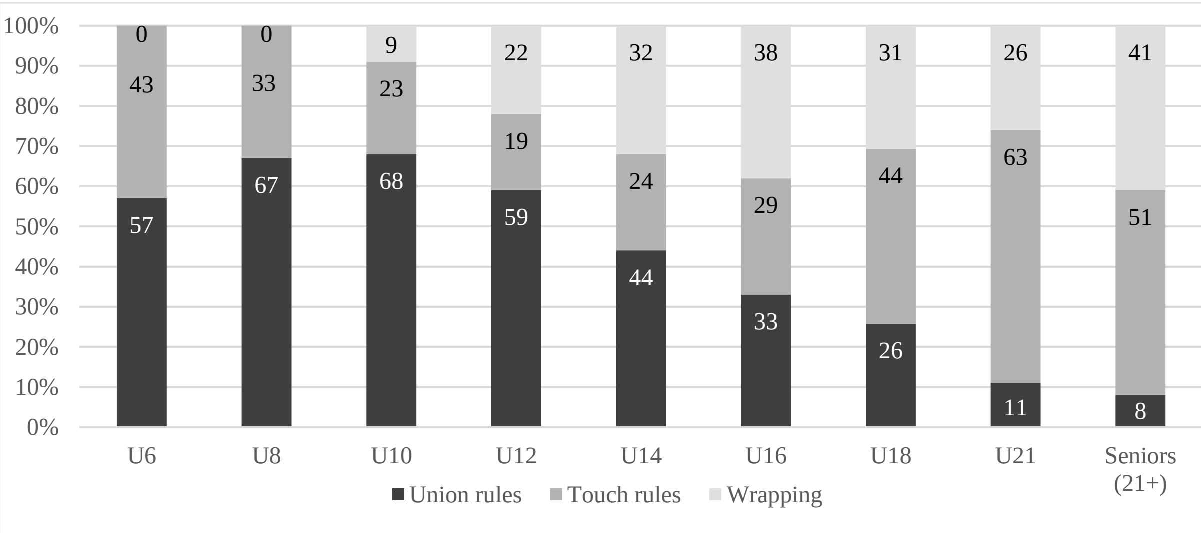

Figure 23. Age category-specific SSG playing rule preference (% of substrata)

The introduction of a physical exercise on external cue was the most prevalent constraint to alter physical activity, with a 53% choice rate. “Two-hand touch”, at 32% choice rate, was the preferred measure for promoting skill development. Tactical awareness was primarily targeted by having the defender take a knee on touch (38% choice rate). In turn, man-on-man marking served to train position specificity (17% choice rate). To promote fun, alternative and/or multiple try areas were most popular (28% choice rate). “Shoulder contact touch in a small area, with defenders’ arms behind their backs”, was contributed to the survey options, as a constraint to promote close contact defending.

6.3.6 Monitoring

Most respondents (64%) never or seldom used GPS to track training activities. Monitoring player load and performance (23%) was strongly related to playing level (Chi^2=73.3; $p \leq 0.00001$; large ES); international (37%) and national (45%) practitioners used GPS most often. In these elite strata of international and professional practitioners, complete omission of GPS was low (<10%), in contrast to 58%, 91%, and 100% at national, local, and school level. Prevalence was thereby highest within experienced substrata (10+ years), with 52% and 45% tracking whole sessions and/or SSG specifically, respectively. Across all practitioners however, only a tenth monitored SSG specifically. Most GPS tracking is applied to U21 (53%) and senior players (54%). Alternative monitoring methods included pre and post fitness assessments (e.g., “yoyo”, “Coopers run”, and “Harvard step”). Access to and finance of GPS-devices forms the main barrier. to be a matter precluding usage.

Table 25 SSG constraints implementation in function of training goals (% choice count / absolute choice count)

	Alter physical intensity		Promote skill development		Tactical awareness		Playing position specificity		Fun		Other		Total
	%	#	%	#	%	#	%	#	%	#	%	#	#
Uneven numbers (teams)	23	*49*	21	*45*	31	*67*	9	*20*	14	*31*	3	*6*	***218***
Defender down/up on touch	34	*61*	17	*31*	25	*44*	12	*22*	10	*18*	2	*3*	***179***
Man on man marking	12	*21*	24	*43*	30	*53*	17	*31*	12	*22*	5	*8*	***178***
2 hand touch	18	*30*	32	*53*	22	*36*	11	*18*	15	*25*	2	*4*	***166***
Defending player drops off	32	*50*	16	*25*	33	*51*	8	*12*	9	*14*	3	*4*	***156***
Offside touch	19	*29*	18	*28*	25	*38*	7	*10*	25	*39*	7	*10*	***154***
Alternative and/or multiple try areas	18	*26*	16	*23*	31	*45*	4	*6*	28	*41*	3	*5*	***146***
Defender back to mark on touch	26	*37*	19	*26*	30	*43*	13	*18*	10	*14*	4	*5*	***143***
Try scored by passing into try zone	13	*18*	26	*36*	25	*35*	8	*11*	25	*35*	4	*6*	***141***
2- player touch	17	*22*	28	*37*	27	*35*	10	*13*	14	*18*	5	*7*	***132***
Defender takes a knee on touch	15	*19*	16	*20*	38	*49*	16	*21*	12	*16*	3	*4*	***129***
1 hand touch	20	*21*	22	*23*	21	*22*	8	*8*	20	*21*	9	*9*	***104***
Physical exercise on external cue	54	*54*	9	*9*	10	*10*	8	*8*	14	*14*	6	*6*	***101***
Neutral player(s)	14	*13*	17	*16*	30	*28*	10	*9*	18	*17*	11	*10*	***93***
Flag touch	15	*14*	25	*23*	20	*18*	7	*6*	23	*21*	10	*9*	***91***
Other	10	*2*	25	*5*	20	*4*	5	*1*	25	*5*	15	*3*	***20***

127

6.4 Discussion

The surging interest for GBT and the claims surrounding it, warrant more differentiated evidence across a broader scope in competitive team sport settings [176]. Research suggests player characteristics such as chronological age and training experience, but not playing level, can affect specific training outcomes [97, 199]. Despite its widespread use, no study currently provides evidence on the design practices and practitioners' characteristics for SSG in RU. Therefore, we aim to discuss SSG^{RU} design by structurally addressing the population sample, training objective, format, field dimensions, duration, constraints, and monitoring of these training forms in RU practice and frame them within the literature.

6.4.1 Participants

Most respondents were NZ-based HC working with male RU players on the local and school level, a role that can entail multiple functions. The observed pyramidal distribution of practitioners in the RU landscape is logically a function of the larger quantity of clubs and players, and therefore a higher demand for staff, at lower playing levels. The underrepresentation of RU practitioners working with female and very young players might indicate niche-positions within RU, warranting specific investigation to obtain a further differentiated perspective, as gender and age differences can impact rugby practice [115, 146].

6.4.2 Training objective

Research has cumulatively stated the concomitant benefits of GBT to include physiological, technical, tactical, intra-, and inter-personal improvements that lead to proficiency in team sports [45, 47, 61, 84, 175, 176, 181, 183, 196, 199, 201, 369, 370]. A quarter of NZ and European-based practitioners use SSG-play to prioritise technical skill and fun enhancement, irrespective of frequency of use. Nearly a fifth of practitioners target physical and tactical development [349], which is equally substantiated by the body of literature [45, 46, 48, 57, 84, 85, 156, 176, 199, 202, 372, 375]. There seems to be a role dependency regarding GBT; AC and HC prioritise skill and fun, S&C focus more on conditioning, and team sport scientists on tactical aspects. Frequent SSG users tend to target tactics more (19%) than their counterparts, relative to total training sessions. Moderate users targeted physical conditioning most often (23%). In turn, infrequent users pursued team building most (25%). Respective to specific SSG format-preferences, developing rugby skills is the main objective. Of note, no format seems to be preferred for recovery purposes.

The available evidence regarding SSG-utility is prolific, sprawling from different perspectives, focussing on various contexts, and using a plethora of methods. We therefore aimed at framing the results of this study holistically, per training objective, in function of RU relevance.

6.4.2.1 Technical skill

The GBT literature on skill enhancement is nuanced; SSG might be effective for improving certain skills measured by specific methods, if pre-specified conditions are met [175, 199, 376]. Mazzeu and colleagues exemplified this in RU by demonstrating 1+1 vs. 1 was the only SSG from three to effectively improve and retain increased passing direction and accuracy in inexperienced male and female undergraduate students [350]. In line with elite coaches' perspective on age-appropriate development in RU, technical skill development through SSG was most prevalent within younger age groups, in our study [172]. SSG^{RU} design can therefore be adapted to obtain specific play, emphasising certain skill sets [172, 173]. Of note, GBT for technique enhancement is a staple across competition levels in terms of relative importance. Within the elite strata (international and professional), the lowest and highest relative use of skill-targeting games were seen. It is unclear whether a difference in time spent focussed on technique, or different training approaches play a role. More HC and AC than other staff prioritise skills. Its importance to practitioners seems independent of their experience-level, which is remarkable considering practitioners grow more knowledgeable and comfortable with GBT over time [176]. Technical skill might play a bigger role in the delivery of SSG to female players than to male players. Studies comparing the influence of SSG training on RU skill in males and females are not available.

6.4.2.2 Socio-affective objectives

GBT has the potential to stimulate players' personal and social development; motivation and enjoyment, and thus fun, can indeed increase through engagement in games [64, 176, 195, 199]. Notwithstanding, only one in ten practitioners in this study explicitly targeted team building, mostly with (pre-)adolescent players. Fun was valued by practitioners throughout most age groups, also peaking around (pre-)adolescence (i.e., U12 (26%) vs. U21 (18%)). Logically, coaches of younger players prioritise fun-experience, considering their socio-affective developmental needs. Having fun was identified as one of the most important experiences for U9 when playing rugby. The development of child-led game-formats therein is vital [173]. Designing and planning adequate SSG and utilising their full potential might be challenging for novice and lower-level practitioners. Coaches' education on this methodology has been reported suboptimal [176].

At school-level, larger and more heterogeneous player groups would be expected, thus making group management through SSG engagement primordial. It is at this level that fun is prioritised most. The complexities of implementing GBT in school RU need to be recognised to optimise this training method [363]. In contrast, the professional nature of elite-level club rugby is a plausible argument for their relative lack of fun-focused SSG.

6.4.2.3 Physical conditioning

Adequately structured and well-delivered physiologic stimuli, including SSG, can improve cardiorespiratory, metabolic, and neurological function [377, 378]. Team sport-contextual evidence demonstrates GBT improves cardiovascular function and sport-specific performance, and compares its effectiveness with high-intensity interval, high-volume, and skill-based protocols [44, 45, 85, 355, 376, 379-381]; Gamble (2004) in RU and Seitz et al. (2014) in rugby league successfully increased the fitness of elite-level rugby athletes using SSG [86, 382].

Our data showed SSG^{RU} are applied increasingly for physical conditioning with rising competition level and are most prevalent in adult players (24%-27%). SSG conditioning is nevertheless recommended throughout the developmental pathway, conditional on an effective prescription [61]. A case can be made for level and age-dependent physical conditioning, as markers of physical performance and anthropometry have been documented to differ between RU playing levels. [98]. Furthermore, significant differences in running and collision-related game metrics were found for four different competition levels [27]. In turn, elite youth and youth sevens matches can require running demands similar to or beyond that of professional club and international rugby [206, 383]. Yet, their movement demands are considered a "stepping stone" to that of senior internationals [384]. Despite existing overlap, distinguishing match demands have also been shown between semi-professionals and professionals in rugby league, and international and provincial rugby sevens [385, 386]. Considering physical fitness is related to performance-determining game behaviours in RU, conditioning should reflect the competition standards [170].

Exercise intensity for effective team sport conditioning should generally be near-to-maximal effort (≥ 90% VO_{2MAX} ≈ 90-95% HR_{MAX}) for "long" periods of time [44, 45, 378]. Various SSG^{RU} formats have been shown to elicit intensities at or above 85 to 90% HR_{MAX} for 64-80% of duration without significant differences in HR, but with significant differences in moderate to very high blood lactate and RPE levels [87, 88]. In contrast, Chadwick et al. (2019) found that most of the time was spent below 75% and between 75-85% HR_{MAX}, respective to their SSG^{RU}-formats [283]. Unfortunately, cross-study SSG^{RU} design varies greatly, limiting the ability to meaningfully compare outcomes.

Despite the disparity in approach, the relevant literature demonstrates SSG training can result in effective, yet suboptimal conditioning; improvements are to specific markers, potentially inferior to alternative methods, and dependent on age group, competition level, playing positions, the individual, and the opposition, without covering all competition demands [28, 45, 85, 219, 291, 376, 379-381]. Consequently, SSG for physical conditioning should be target group-specific and supplemented by complementary, controlled, needs-based training modalities, to prepare rugby athletes for the full range of rigours in their competition [27, 28, 41, 381].

6.4.2.4 Tactical objectives

GBT is deemed an "interesting methodological resource" for tactical improvements in team sports [175]. Though fun and skill remain the priority for youth coaches, our results showed SSG for tactical objectives are relatively more popular in most youth categories, compared to adults. However, tactical considerations were present for male players only. A larger sample size is likely to shed more light on the female player cohort. Tactical behaviour can differ during SSG for age groups in youth soccer players [202], but no specific evidence is available for RU [97]. Very experienced practitioners used SSG more readily (21%) to train tactics, indicating a positive relationship between coaching experience and tactical games. This contrasts the lower prevalence of tactical SSG^{RU} at the international level (12%) compared to all other levels (≥16%). However, the results suggests that where SSG were applied more frequently, they were aimed at tactics more often.

Systematic review of team sports and especially football SSG suggests that design elements, playing constraints, and player characteristics (e.g. field dimensions, player numbers, number of ball contacts, off side) affect tactical behaviour and collective dynamics of teams (e.g. inter and intra-team space, lower defensive complexity) [175, 202]. Documented tactical adaptations are varied, study-specific, and subject to definition and interpretation (e.g., "greater decision making", "better tactical adaptation"), and should therefore be interpreted with caution [175, 202]. The literature outlines an existing discrepancy between qualitative (favoured) and quantitative methods used in coaching regarding GBT for competitive team sports [176]. Empirical data also shows personal and social development (e.g. increased task responsibility, player autonomy, improved communication and teamwork) with SSG, making them very appropriate for the (pre-)adolescents age groups targeted most, i.e. U10 – U16 (18% - 21%) [176]. Yet, intra-, and interpersonal benefits are often modelled conceptually [62, 84, 181, 183, 184, 387]. The transfer of tactical improvements to competition has been questioned for soccer SSG but investigations are currently absent [59]. Specific tactical adaptations should be clearly delineated and targeted within the specific performance context. Therefore, the tactical aspects of SSG^{RU} require further well-structured investigation.

6.4.2.5 Summary

It is evident that practitioners' training objectives within SSG training evolve according to their experience and their target population. We can reasonably assume that practitioners use GBT at younger and amateur levels for skill development, fun, and team building primarily, while practitioners on the (young) adult and professional levels orient SSG more heavily towards physical conditioning. It is essential to realise that the nature of RU games can be altered to prioritise key behaviours and skills through their design. For this reason, training objective should guide SSG^{RU} design. Limited evidence is currently available for RU practice.

6.4.3 Format

A variety of SSG formats is predominantly used in RU practice [349]. The results suggest format preference might depend on the available possibilities practitioners have to apply various games. Yet, moderate player numbers (three to seven-a-side) seem essential to RU practitioners for GBT, similar to what Bujalance-Moreno and colleagues recommended for soccer players [296].Very low and very high player number-formats are additionally used for specific rugby skills, and specific and aerobic match conditioning. In complement, Vaz and colleagues saw differences in kinematic and physical profiles, but not HR, for 1v1 and 2v1 evasion games, compared to 7v7 [87]. The results indicate that (semi-)professionals lean more towards medium to LSG as opposed to amateur practitioners preferring SSG. Parallel to the amateur level, youth practitioners tend to apply smaller formats more readily, which could be for increased ball handling. On the senior level, a wider variety is applied. Of note is that 1v1 training seems a valued addition across levels, logical considering the proclivity for skill development in GBT. The observed emphasis on 1v1 in the youngest players, three-a-side for all youth, and a further incremental increase in player numbers with rising player age is also logical, as adding players increases the complexity of the performer-environment relationship [84]. A larger array of SSG formats was seen for NZ, as opposed to European practitioners. Staff role and player sex show clear differences for SSG format selection; generally though, low to moderate player numbers are preferred (i.e., three to seven-a-side).

The body of literature regarding rugby lacks structural approach towards investigating the effects of SSG designs on outcomes, despite initiatory efforts in RU [87, 88, 97]. A high degree of heterogeneity in team sports SSG research has meant clear inferences are hampered [46, 48, 49, 199]. The current consensus is that format selection can alter training stimulus, in which fewer players seem to cater for higher physiological demands when surface area is kept constant [48, 88, 97, 201]. Our data suggests that practitioners prefer SSG for rugby skill development and LSG for physical conditioning, which has not been documented in the literature.

6.4.4 Field dimensions

Reported SSG pitches are roughly a third, half, or 65% (circa. 33x23m, 45x32m, and 65x46m, respectively) of a RU field (100x70m). However, this interpretation of 'labelled' pitch sizes (S-M-L) varies greatly within and between practitioner roles, competition level, and age categories. Notably, the largest "small" pitches were for the youngest players, complemented by the largest inter-subject variance. Coaches of (pre-)seniors, sport scientists, and S&C seem to utilise larger and smaller pitches, as compared to their colleagues. This contrast in field dimension extremes is further evident for opposite competition levels, i.e., local/school vs. international.

A variety of pitch dimensions has been used in SSG^{RU} research: 15x12m [350], 20x40m [343], 30x70m [283], 39x51m [344], 60x40m [89, 306], and 30x30, 50x35, and 100x70 [87]. Two studies did not specify field dimensions exactly [28, 86]. No methodological rational is evident nor justification given, apart from Kennett and colleagues who doubled the field dimensions (32x24 and 64x48m) to determine the influence of player number and pitch size [88]. This disparity congruent with soccer-based research [49]. Scarce direct and specific evidence, and inconsistent research designs limit the ability to form meaningful parallels; some research suggests field dimensions may not alter technical demands in soccer [49], whereas other research reports an increased technical component during SSG in youth rugby league, Australian rules football, and indeed soccer [97]. Likewise, the influence of pitch dimensions on time-motion and physiological responses is nuanced. Yet, the common understanding in the football codes literature is that larger individual area elicits higher demands [48, 49, 88, 97, 201].

Since contradicting evidence exists, its practical relevance is subject to the practitioner's interpretation of the selected variables and metrics used to measure intensity; which specific outcome is desired [49]? Investigation of SSG^{RU} suffers equally from confounding factors regarding the isolated effect of field dimensions [28, 86, 87]. Yet, Kennett and colleagues do provide evidence that larger pitches combined with less players are more taxing [88]. Parallel to the literature, the results show practitioners do not consensually view SSG field dimension, nor apply standardisation. RU practitioners generally seem less prone to utilising extreme field sizes. But a high competition level, S&C or sport scientist background, and senior age group squads could be indicative of less conservative field dimensions for SSG^{RU}.

6.4.5 Duration

Most RU practitioners run SSG for two to ten minutes, preferentially organised in three bouts of four to six, or eight to ten minutes, and interspersed by two-to-four-minute recovery. Various studies in the football codes have demonstrated effective enhancement of aerobic endurance and specific performance markers by implementing similar programming to SSG and HIIT-protocols [44, 45, 179, 209, 355, 356, 375]. Practitioners that choose longer durations concurrently tend to use SSG for technical skill development and fun, as compared to shorter durations for team building or tactical and physical training. A minimum threshold-exposure of two to four minutes at ≥90% VO_{2MAX} (≈ 90-95% HR_{MAX}, ≥15 RPE) interspersed with up to two minutes of relief, or more than four to five minutes of active recovery (60-70% VO_{2MAX}), is recommended to promote neuromuscular and cardiopulmonary development [377, 378].

A 4x4-approach (four times four minutes at 90–95% HR_{MAX}, interspersed by three minutes jog at 50-60% HR_{MAX}) was devised by Helgerud et al. (2001) to improve aerobic fitness in football players, but only Weakley and colleagues have adopted a similar structure (6x4) in RU [44, 343]. These prerequisites might not be met in some cases, in practice, as longer duration would likely impinge on the capacity to uphold a near-maximal output. It is therefore remarkable that researchers have consistently designed longer durations in SSG^{RU}, for up to two bouts of twenty minutes [87-89, 283, 344]. Our survey results outline a work to rest ratio (W:R) of between 1:1 and 5:1. The relevant literature indicates that external loads are not significantly affected by various W:R, but continuous games and longer bout-duration (>6 minutes) cause higher internal loads, when total time is equated [97]. The accumulation of more work over time increases load. However, the quality of the work is not necessarily accounted for, and different specific measures might not yield uniform outcomes.

A trend is apparent for practitioners to select shorter SSG^{RU} (two-to-six-minute intervals) for rising competition levels, experience, and player age, versus longer bout-durations on lower levels, by novices, applied to youth players. The former are indeed in accordance with the evidence [44, 45, 378].. Longer-duration SSG could be applied due to practical convenience or lack of specific knowledge or conviction, as supported by the need to grow into the coaching role [176]. Additionally, practitioners noted a lack of time for sports subjects taught at school-level leads to being selective with training components like skill development, strengthening the argument to work in short(er) high-quality bouts. The data shows that competition level and target age-group, as well as experience level to a lesser degree, influence the selection of SSG duration in RU practice.

6.4.6 Constraints

When specified, a plethora of playing constraints have been applied to SSG^RU studies, including evasion setups [87], sevens' rules [87], modified touch rules [88], 2011 IRB rules [89], mixed rules [86], and "traditional" and "adapted" youth rules (RFU U9) [173]. This body of research documented that different playing formats and rules can impact acute and chronic physical, physiological, and kinematic outcomes, youth players' game behaviours, as well as differentiate for playing experience. In practice, wrapping, and especially tackle and touch rules were prevalent in SSG^RU. Both contact and non-contact SSG^RU have been shown to elicit high physiological stress, representative of match demands. A lack of tackling could furthermore reduce injury risk, while higher running demands enhance general conditioning [283]. A variety of passing rules are used in practice, but four to six backwards passes were preferred by practitioners before a turnover. The observed variance is indicative of the perceived utility of constraint manipulation in RU practitioners, but the effect of most rules has not adequately been investigated.

In contrast to the consensus that direct supervision and coaching increases training intensity, adherence, and improvements in SSG [48, 49], verbal feedback was not effective at increasing kinematic, perceptual, or physiological markers in SSG^RU [343]. Aside from contextual factors, a difference might exist between 'encouraging' and 'informing' for effective performance stimulation. Different applications of various constraints (e.g. tackle/touch forms, on/off side, forward/backward ball passing, added exercises, retreating defensive line up) in rugby league have been shown to impact training outcomes differently in terms of internal and external loads, and technical characteristics [97]. However, only two studies have investigated the isolated influence of a specific constraint in a RU sample [283, 343].

Our results demonstrate practitioners vary and differentiate SSG; unbalanced teams and numerical surplus-situations, often achieved by tasking defenders, are most popular. This speaks to the tactical aspects of SSG^RU. Additional physical exertion (e.g., down-ups) is popular for conditioning and two-hand touch is preferentially applied for skill-development. In turn, man-marking and defenders kneeling are popular for tactics. Lifting scoring potential restrictions is used for fun experience. Of note is the dichotomy seen for competition level and age categories; the lower the competition level and the younger the player, the more tackling is implemented. This observation is in stark contrast to the ongoing debate about player safety, especially in youth, school, and amateur rugby [36, 38, 76]. More so, because of the role of tackling within this discussion [11, 33, 37, 74, 79, 126, 130, 133, 388].

It seems suboptimal to apply tackling to youth and amateur SSG^{RU} considering non-contact SSG^{RU} can provide an equal or potentially superior conditioning stimulus with reduced injury risk [283], and more dynamic youth rugby rules optimise the rugby experience in the developmental pathway [173].

A connection with coaching experience could be postulated, as moderately experienced practitioners preferred tackling in SSG, versus more experienced practitioners showing a more balanced approach. In turn, novice practitioners seem to shy away from using tackling in SSG^{RU}. Differences relating to specific roles seem inherent; S&C' focus on aerobic conditioning would require less tackling [283], whereas other technical staff target rugby-specific skills. The preference for wrapping in female players is an interesting observation. And the higher implementation of tackling by NZ versus European-based practitioners (45% vs. 8%) contrasts reportedly "successful" surveillance and prevention systems put into place [388]. But the results should be framed in the limited scope of this study.

Holistic programmes for the appropriate long-term development of players, including mastering of techniques like tackling in controlled settings, are essential during the formative years [38, 72, 76, 141]. As constraints ultimately dictate the response to SSG training and are therefore critical in meeting objectives, future RU-specific research is required to clarify the role of particular constraint manipulations on physical characteristics, and technical and tactical behaviour especially [97].

6.4.7 Monitoring

Research supports the utility of microsensor devices, in team sports like the football codes, and states its use is widely spread in RU, among other sports [28, 118, 122, 217, 250, 256]. This notion of extensive use is not supported by our findings as two-thirds of RU practitioners did not or barely use GPS. Parallel to soccer and rugby league, this equipment seems reserved for very experienced RU coaches in senior elite environments [101, 389], to ascertain whole training loads rather than specific SSG^{RU} loading, akin to the research [28, 306].

Evidently, professionalism drives this clear level, experience, and player age-based discrepancy. A cost-benefit argument can certainly be made for most of RU practice. Microsensor-devised kinematics are strong indicators of internal and external training load[123], but they constitute a useful luxury in light of low-cost and valid alternatives like HR and RPE [215, 235, 263, 264].

These accessible variables have been applied to SSG^{RU} and can complement each other to provide a differential perspective [88, 216, 343, 344]. An adequate intensity of 90-95% HR_{MAX} or ≥15 RPE for minimally three minutes can be monitored [44, 377, 378]. To complement, respiratory rate (breaths·min^{-1}) is an easy and accurate measure of adequate intensity [263]. Relevant field-based fitness tests already used by practitioners, as stated in the results, can provide an indication of progress [230, 232].

6.5 Conclusion

This study for the first time describes the design and application of SSG in different performance contexts of RU practice and contrasts it with the current body of knowledge. Practitioners in this study tended to implement SSG with moderate player numbers and of moderate duration, to improve technical skill and socio-affective factors primarily. Physical conditioning and tactical aspects are also important. Evident differences in design relate to competition and experience level, target groups, and specific role. More elite practitioners' SSG training seems more congruent to the research; high-level coaches to senior players tend to target physical conditioning more by favouring medium to LSGs, for shorter durations, using various field dimensions and microsensor devices. Lower-level and youth coaches favour longer-duration SSG on less varied pitches, to target fun and technical skill. Various constraints are applied to SSG^{RU}, with tackling being more prevalent at lower player age and playing level. SSG design is not standardised in RU and practitioners' performance contexts differentially influences their SSG application. Practitioners' delivery of SSG^{RU} should be guided by specific training objectives and novice, youth, and school practitioners should be educated on the full potential of GBT.

6.6 Limitations

Despite a wide exposure of the survey, the authors recognise the limitations of its return. Certain cohorts might provide an incomplete perspective relative to the variable investigated. The participants' characteristics were made available and should be considered when interpreting the results. Important to note, the survey provided participants with balanced teams (equal player numbers) SSG only, when selecting formats.

KEY POINTS

- **Point 1** – Most coaches in RU use two or three bouts of three to seven-a-side SSGs with a 1:1 to 5:1 work-rest ratio, for short durations (2-10 minutes). The main objective is to improve technical skill and fun.
- **Point 2** – Practitioners' performance contexts relate to their SSG^{RU} design: player number, field size variability, physical conditioning, and the use of microsensor monitoring grow as competition level and player age rise. Concomitantly, bout duration, the use of tackling, and fun targeting diminishes.
- **Point 3** – SSG^{RU}-research should be practice-informed: study designs lack a focussed line of investigation and do not account for practitioners' different contexts. RU practice should be evidence-based: SSG design should reflect the needs and challenges of the specific performance context by targeting clearly objectified outcome measures during high-intensity, high-quality work bouts.

CHAPTER 7

The influence of small-sided game design variables on the acute demands in rugby union youth

Chapter prelude

The thesis so far, has identified the importance and specificity of rugby, and the role SSG play in RU practice. We established that SSG^{RU} are prevalent and various formats are applied to serve several uses in training, such as fun, technical skill, physical condition, and tactical training. Our investigation has thereby revealed that practitioners differ in their design of SSG and the application to various player cohorts, depending on their contexts. However, we had previously established that the available body of knowledge is insufficiently developed to provide adequate information for designing SSG for a RU population, and less so for youth RU players. Therefore, in Chapter 7, we will examine the kinematic, physiological, and physical demands of practically relevant SSG in various youth RU age cohorts.

7.1 Introduction

Rugby union (RU) is a fifteen-a-side contact sport with a high-intensity intermittent nature [22]. Rugby participation is rising globally, and its popularity has been documented in New Zealand (NZ) and overseas for school-age youth, as it is part of educational curricula [16, 70, 74, 75]. One training method that has been used extensively in practice to prepare players for these demands are small-sided games (SSG) [349]. This form of game-based training (GBT), in which full-sided games are adapted to suit training purposes, are reported to benefit physical, technical, and tactical aspects of team sports [59, 61, 83, 175, 176, 201, 390]. These benefits are modelled to occur through the provision of decision-making opportunities influenced by functional constraints within the performer-environment relationship [84, 184, 192]. There is a growing body of evidence regarding SSG, with limited attention for rugby league (RL), and especially RU [46, 96, 201]. Among RU practitioners, SSG are mostly implemented below the senior level, including the school-level [349, 391]. Considering this scarcity in RU, the knowledge surrounding SSG design is incomplete [59, 96, 97, 392].

The broader body of knowledge indicates that manipulation of design factors can alter acute training outcomes [46, 59, 201, 390]. As such, a practice-based review has shown that dependent on their contexts, coaches implement a variety of constraints like playing and recovery bout duration, contact rules (tackle vs touch vs wrapping; e.g. two-hand touch), alongside various other rules such as inserting physical tasks (down/ups), and marking for specific players [391]. Elemental design factors are the most investigated, and studies tend to show that increased pitch size and decreased player number may increase the physical, physiological, technical, and tactical demands [46]. Exemplary markers of these demands are variations in HR, blood lactate levels, $VO2_{MAX}$, RPE, and distance, but also passes, shots and tackles, as well as individual and team auto-organisation leading to new formations [59, 201, 390]. In addition, task constraints related to rule changes can alter SSG outcomes; e.g., off-side rules were shown to produce more skill executions such as passes and induce greater kinematic load such as total distance (TD), than on-side rules in RL [200].

In complement to these generalised conclusions, several reviews have alluded to the evidence not being sufficiently strong to broadly extrapolate due to a lack of consistency between studies in terms methodological approach (e.g., experimental design, sampling strategy, training regimens, task conditions), study samples (e.g., seniors, youth, playing level, sports), and measured outcome variables (e.g., kinematic, physiological, perceptual, tactical, technical, measuring equipment) [46, 48, 59, 96, 201]. Most of this research is conducted in soccer. Across sports, oftentimes, senior elite-level players are targeted in their professional environment, which may not transfer to other populations. The methodological transparency required for replication also varies between studies. These factors hamper the ability to dissect specific causal mechanisms regarding design factors such as pitch size and player number, over other confounding factors like playing rules and coaching [46, 49]. This lack of structural approach makes it difficult to directly compare results, find conflicting evidence and consequently, draw strong conclusions. Systematic review of the literature has exposed study quality in SSG to be lacking [96]. Clemente and colleagues exemplified this by indicating increases or decreases in field size promote some tactical aspects but restrict others [202]. A standardised approach is recommended to improve the body of literature.

In the rugby codes, the sum of evidence remains limited; most studies on the effects of constraint manipulation have been performed in specific senior RL contexts [97]. Pre and post intervention testing has indicated that GBT could chronically improve physical performance markers like heart rate (HR), running speed, and sprinting ability [57, 382]; however, no information is available about chronic improvements in technical and tactical aspects [97]. Cross-sectional studies have demonstrated that constraints relating to pitch size, player number, playing rules, work-rest ratio, and duration do lead to various outcomes in physiological and physical measurements, as well as in skill-related performance. In addition, individual factors like chronological age, playing experience, and available information such as inter-game performance feedback or coaching seem to affect outcome measures [97].

As such, Foster et al. (2010) demonstrated that 4v4 and 6v6 elicited HR ranges of 85-91 $\%HR_{MAX}$, with higher values in 4v4 in RL youth [209]. In turn, Gabbett et al. (2012) showed for elite male RL players, that non-contact SSG resulted in more TD covered and within (very) high-speeds bands, a higher average speed (V_{AVG}), and more maximal accelerations, but similar total technical involvements such as catching errors and total passes, compared to contact SSG [56]. Sampson et al. (2015) concluded that similar TD are covered irrespective of work/rest interval duration, but the decline of high-speed distances was greater in consecutive one-minute bout SSG, as opposed to longer bouts, indicating an influence of bout duration on pacing strategies in amateur junior male RL players [393]. In general, it seems that larger pitch sizes and less players create higher demands. In addition, individual factors like chronological age, playing experience, coaching, performance feedback seem to affect outcome measures [97].

This young body of literature generally concurs with the broader evidence on the physical aspects, but the current weight of the evidence is low. Limited clarity and replication of specific conditions make it difficult to parse out direct and isolated causal relationships between design variables and effects. A systematic review of SSG in the rugby codes demonstrated that the evidence is incomplete, especially in RU and 7s, such that conclusions should be interpreted with reservation [97].

Despite the abovementioned limitations, GBT is popular among RU practitioners [349]. Some elite coaches believe SSG play an important role in player development, and RU youth engagement can be optimised with adequate constraint management [172, 173]. Specific studies on design variable effects in RU youth are lacking from the research however [97, 354]. Game design has been shown to effectively accentuate youth-appropriate game behaviours like runs with the ball and successful passing in U9, as well as ameliorate their game-experience [173]. Limited research furthermore suggests physical and technical performance during SSG^{RU} is influenced by playing experience but not necessarily age, and it has been purported to help with talent identification [89, 306].

Considering these SSG have been shown to have the potential to approach, and even exceed, certain RU match running demands, they can be used to effectively condition professional RU players [28, 86]. Conditioning intensity can thereby be reached without technical or tactical proficiency [89]. For this, one study within RU has demonstrated that lower player numbers and larger pitches were associated with increased running demands, rating of perceived exertion (RPE), and blood lactate, but not HR [88]. Of note, distinctions between outcomes for exact SSG formats were missing. Nevertheless, various SSG formats with specific field dimensions, playing rules, and objectives catered to specific RU cohorts are typically prescribed to differentially emphasise physical, physiological, technical, and tactical outcome measures in RU players [87, 345, 347].

This emerging research is increasingly indicating that the design of SSG is instrumental for providing the desired training stimuli through manipulation of playing constraints in specific RU cohorts [97, 348]. Within the rugby population, different experience-levels, and some, but not all, age groups might perform differently in GBT [56, 89, 306]. Therefore, the different cohorts investigated in the RU literature should not be simply extrapolated or generalised to an adolescent cohort. The current state of the evidence has mainly investigated the influence of basic design factors on individual outcome metrics through univariate analyses on the senior (semi)professional level [87, 88]. No comparative studies have investigated adolescent SSG^{RU}, to clarify the impact of elemental design factors on SSG^{RU} performance. Consequently, this investigation aimed to use standardised SSG^{RU} (3, 5, 7-a-side; S- medium (M)- L pitch) on NZ U14 to U18 school-level players to, firstly, identify the influence of the elemental design factors player number, pitch size, playing bouts, and age category, on the generic performance outcome (i.e., grouped kinematic, physiological, and physical performance variables). And secondly, to establish how player number and pitch size affect the most relevant core performance metrics.

7.2 Methods

7.2.1 Experimental approach

This study consisted of an experimental design with cross-sectional data collections on randomised NZ secondary school-age rugby players. Availability sampling was used with the inclusion criteria of sufficient numbers of representative male school rugby players. The experiments ran from preseason 2020 to midseason 2021. Heart rate (HR), kinematic, and perceptual data were collected using wearable VX SPORT™ microsensor technology (VXWR5Lb; 10 Hz GPS, Glonass, QZSS, SBAS, Galileo & BeiDou compatible; tri-axial 100 Hz accelerometer, magnetometer, and gyroscope), coupled Suunto HR monitors, and the Borg scale (6-20) [264]. Injury occurrence was additionally noted. Institutional ethical approval was obtained (HREC(Health)2019#16).

7.2.2 Participants

Two hundred and fourteen NZ male youth rugby players, comprised "tier 0" to "tier 2" participants according to the Participant Classification Framework [394], officially participating in year 9 to year 13 school rugby training and/or competition, were recruited for cross-sectional data collections. 0riginal sample size calculation aimed at surpassing samples from representative study populations and topic [16, 56, 206, 207, 209] (n=15-40; n_{MEAN}= 25), per condition. Longitudinal availability and convenience sampling were applied to maximise sample size. Five Bay of Plenty regional secondary schools' sport departments agreed to participate. Data collection was completed during and outside of school times to accommodate and maximise voluntary participation and compliance. Following attrition and attendance requirements (no-show, withdrawal, 2020 Covid pandemic), 158 U14 to U18 were randomised into age cohort-specific conditions (age 14.8 ± 1.4 [range 13-19]; height 174.5 ± 7.5 cm; mass 77.2 ± 17.1 kg).

Table 26 Subject characteristics

	U14	U15	U16	U18	U14+U15	U16+U18
N	57	52	8	41	109	49
Age	13.6 ± 0.5	14.4 ± 0.5	15.4 ± 0.5	16.7 ± 1.0	14.0 ± 0.6	16.5 ± 1.0
Height (cm)	171.7 ± 5.9	172.7 ± 7.3	178.0 ± 4.1	179.7 ± 7.2	172. 2 ± 6.7	179.4 ± 6.8
Weight (kg)	74.6 ± 15.4	71.9 ± 16.1	77.5 ± 23.2	87.3 ± 14.4	73.3 ± 15.8	85.6 ± 16.7

7.2.3 Data collection procedures

Experimental data was collected on eight occasions between February 2020 and May 2021. Climatological conditions varied without extremes and were representative for the rugby season (12-25 °C; 48-97% humidity, 1007-1026 mbar, uncovered natural grass pitches). Participants were initiated in the use of the microsensor units and the Borg scale [264]. Personal and anthropometric details were gathered within a month of SSG. A 40 m straight-line maximal sprint determined players' top speed (V_{TOP}), and a "bronco" (rugby-specific 1200-meter shuttle run) was used to establish maximal heart rate (HR_{MAX}) [211, 212].

Microsensor technology, including VX SPORT™, has been applied to team sports and especially the football codes, including rugby youth and 7s research [16, 101, 115, 118, 120, 216]. Review of the literature shows 10 Hz GPS to be adequate for measuring most rugby-related movement demands [245, 246, 252, 255, 256, 395-397]. A mean value of 77 ± 6% for positioning quality during match-play has been demonstrated for similar equipment [398]. To secure a good signal (4 – 12 satellite connections, >80% GPS time coverage), the microsensor units were activated on pitch side approximately 15 minutes before being allocated. The units were worn between the scapulae in purpose-built vests. Rating of perceived exertion was collected verbally from individual players in group setting immediately after each playing bout.

Participants were provisionally randomised into SSG formats and reserves per age category, using a table of random numbers, one day prior to data collection. A 5-to-10-minute player-led warm-up was undertaken under coach supervision, followed by three, four-minute bouts of a SSG format under researcher supervision [44, 45, 391]. Commonly used three, five, or seven-a-side "touch rugby" was played on ⅛ (small (S)= 25x35 m / 875 m^2), ¼ (medium (M)= 35x50 m / 1750 m^2), or ½ pitch (large (L)= 50x70 m / 3500 m^2) (Figure 24) [391]. Three minutes of active recovery interspersed work bouts during which the players were instructed to lightly jog [44, 45, 391]. Playing rules included five touches (two hands; retreat ~5 steps) before a turnover, backwards passing only, no tackling, penalties, or lineouts. No coaching, encouragement, or feedback was allowed from coaching staff. No substitutions were made during the games.

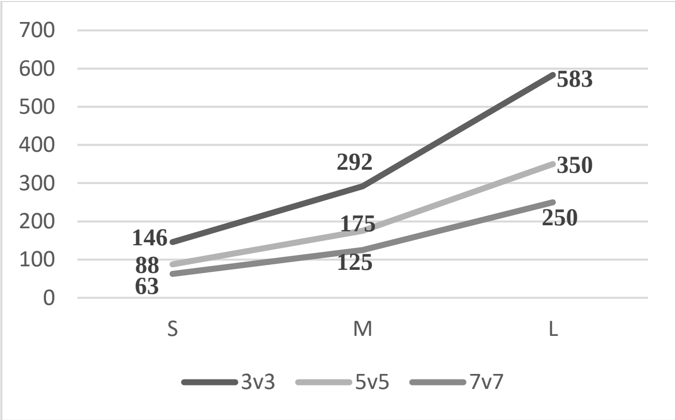

Figure 24 SSG format relative playing area (m^2/player)

Pseudo-randomisation of SSG order was pursued across data collections by rotating formats to differ from previous collections, while accounting for the specific collection's practical suitability and the logistical feasibility for total data collection. Where applicable, a minimum rest of fifteen minutes was provided between multiple SSG. Players were allowed to consume water *ad libitum*. Self-monitoring of safety and autonomy of involvement was administered. Injury surveillance was informed by prior research in rugby and for practical reasons considered to be "any change that occurs during the games, that is to any degree worrisome to the player or staff from a logical and common-sense perspective" [11, 79].

7.2.4 Data handling procedures

Microsensor data, including kinematic and HR-based measurements, were downloaded using the manufacture's software (VX View version 5.4.3.53). Participants' data files were trimmed and coded for playing time; full SSG (18 minutes) and SSG bouts (4 minutes). Data cases were visually and numerically inspected to identify technical malfunction or user error (i.e., interruptions, flatline, extreme values). Corrupted data was removed from further analysis. Cases containing partial metrics were coded with missing values, and useful outcome variables were retained for further analysis. A total of 1,309 data cases (305 SSG and 1,004 bouts) were retained for statistical analysis of respective outcome measures. Full SSG (18 mins) and individual bout (4 mins) data were analysed separately, for age cohorts; total youth (U14,U15,U16,U18), pooled youth (U14,U15 + U16,U18), and individual age groups (U14+U15+U16+U18).

A broad selection of 52 absolute and relative outcome measures informative to the research questions were analysed for multivariate effects (i.e., "*overall performance*"), relating to (1) *kinematic* performance, such as speed, impact, accelerations, and ActivityLoad3D (i.e., solely movement-based variables); (2) *physiological* performance, such as HR and work-recovery ratio (W:R); and (3) *physical* performance, such as AthleteLoad, RPE, and injury occurrence (i.e. composite and/or arbitrary measures). These measures included various speed and HR zones (V_Z and HR_Z, respectively).

Specific follow-up outcome measure selections commonly used in rugby and SSG research were further analysed; twelve "*general performance measures*", three absolute high-intensity running (HIR) categories, and five relative V_Z and HR_Z were reported in Appendix 10: Youth SSG general performance measures (imputed values - R), Appendix 11: Youth SSG relative speed zones (imputed values - R), and Appendix 12: Youth SSG relative heart rate zones (imputed values - R) [26, 97, 282, 352, 383, 399]. Of these twenty-five measures, a selection of eight "*core performance measures"* were presented in-depth in the results (Table 34a-e), selected based on work from Kennett and colleagues [88].

Nominative labels were based on the software package; values and categories relative to individual players' maxima were consequently integrated in conjunction with the literature [93, 122, 275, 276]. The V_{TOP} and HR_{MAX} were based on the highest absolute recordings during baseline testing or SSG, whereas maximal speed (V_{MAX}) refers to the highest speed performed during SSG. Sprints were defined as an increase of $\geq$0.69 $m \cdot s^{-2}$ to reach $\geq$10 $km \cdot h^{-1}$ [280]. Where players' HR_{MAX} was unavailable, a theoretical age-specific HR_{MAX} was calculated using (208 – 0.7 x age) [234]. Rating of perceived exertion and injury occurrence were transcribed from the manual notion documents to an Excell spreadsheet.

Absolute HIR categories were set to converge with benchmarks put forward in systematic research; high-intensity running distance (HIRD >18 $km \cdot h^{-1}$), high-speed running distance (HSRD >20 $km \cdot h^{-1}$), and very high-speed running distance (VHSRD >25 $km \cdot h^{-1}$) [93]. High-intensity acceleration (HIacc) and deceleration (HIdec) thresholds were kept to the manufacturers setting of 3 $m \cdot s^{-2}$, based on prior rugby research [115]. The V_Z provide a more appropriate perspective on youth and lower-level play [277] and were defined as <20% (z1), 20-50% (z2), 51-80% (z3), 81-95% (z4), 96-100% (z5) V_{TOP} [24, 118, 278]. The HR_Z were adapted from Higham et al. (2016), based on Edwards (1993) to be ≤59% (z1), 60–69% (z2), 70–79% (z3), 80–89% (z4), and ≥90% (z5) HR_{MAX} [275, 279]. A VX Sport metrics glossary is available [280].

7.2.5 Statistical analysis

Established data cases were exported from the manufacture's software to an Excel worksheet (Excel 2016, Microsoft Office). Absolute data was normalised (min^{-1}) to complement full-duration SSG values. In a first phase, SPSS software (IBM SPSS Statistics Version 29) was used to calculate descriptive statistics reported as mean ± standard deviation (SD) and for multivariate analyses of variance (MANOVA). In a second stage, parallel univariate analyses of variance (ANVOVA) were performed with pairwise differences in R 4.3.0 (R Core Team, 2023).

Main and interaction effects for all groups defined were calculated using one, two, three, and four-way MANOVA for *overall performance*, and *general performance* measures, which include HIR categories, TD in V_Z, and time in HR_Z. These analyses were executed for pooled (Table 28) and differentiated age groups (Appendix 13: Youth SSG age cohorts multivariate tests (complete cases - SPSS)). Automatic listwise exclusion of cases with missing values for any dependent variables (MANOVA in SPSS) led to omission of valid data for specific outcome measures. These omissions combined with limited data for select combinations of independent variables (SSG design variable levels) and dependent variables (performance measures) meant normality of distribution and homogeneity of variance (Levene's test) could not be statistically computed or confirmed for MANOVA in SPSS. Consequently, no pairwise comparison was sought in SPSS.

In mitigation of these limitations, a random forest imputation method in R 4.3.0 (R Core Team, 2023) was used on 254 incomplete cases with ≤4 missing values to increase the total number of complete cases from 822 to1,076 out of 1,309 cases [400, 401]. Forty of the 52 dependent variables were included after exploratory correlational analysis for subsequent three and four-way MANOVAs of SSG (251 cases) and bouts (837 cases). Pairwise comparisons were conducted following independent ANOVAs for each of the general performance measures (25), for age groups, SSG, and average bout. Model diagnostics were limited to Levene's, Shapiro-Wilk, and Mardia's tests.

As normality and homogeneity were not confirmed for all combinations of factors and quantitative variables, an informed choice was made by the authors to assume normal distribution and homogeneity based on the rigorous initial graphical and numerical assessment of the raw data, the large sample size and the large number of SSG bout cases per group (>30) on most occasions, as well as the robustness of (M)ANOVA and the lack of power to detect statistically significant differences with non-parametrical analysis (Kruskal-Wallis) [402].

Main and interaction effects were interpreted through Wilks' Lambda. Statistical significance was set at $p \leq 0.05$ and trends to significance were reported for interpretation as $p = 0.05 – 0.10$. Effect size (ES) was reported as partial eta squared (η^2) for multivariate outcomes (Table 28). A posteriori observed statistical power was presented with $\beta = 0.20$ (Pr >0.80). For multiple comparisons Bonferroni correction was applied [281]. Confidence intervals (CI) were calculated as 95% CI. Interpretation of pairwise differences between performance outcomes was solely based on the R-generated imputed data set to maximise extrapolation.

7.3 Results

A total of 1,004 SSG bouts were included, forming 305 full SSG across participants, for which one or more outcome measures were analysed. Four participants chose to discontinue their SSG due to minor injury, including one recurrent old discomfort (59.8 injuries per 1000 player-hours). Frequencies of SSG formats for which at least one outcome variable was collected are reported in Table 27. The interaction and main effects show that all SSG design variables influence full SSG and individual bout performance directly ($p < 0.001$), with pitch size and player number being the main drivers, and most elemental design variables can mitigate each other's effects on overall performance outcomes ($p < 0.05$) (Table 28). Furthermore, different analytical techniques can lead to minor differences regarding interaction effects.

Separate analyses using two and three-way MANOVAs (cf. SSG/bouts) with complete SPSS cases within U14/U15 pooled, and within U16/U18 pooled, revealed all statistically significant main and interaction effects for the younger ($p \leq 0.001$) and older cohort ($p \leq 0.01$), apart from pitch size*bout ($F = 0.922$; $p = 0.735$) and player number*pitch size*bout ($F = 1.094$; $p = 0.220$) in the older cohort, for bout data. Multivariate analysis of complete cases with pooled U14/U15 and U16/U18 as age factor also showed significant effects ($p \leq 0.01$) for all variables, but pitch*bout ($p = 0.078$) and age*bout ($p = 0.363$). Within individual age categories, changes in interaction and main effect magnitudes occurred when overall performance was contrasted with specific outcome measure selections (i.e., general performance measures, TD in V_Z, or time in HR_Z), as reported in Appendix 13: Youth SSG age cohorts multivariate tests (complete cases - SPSS). Thus, indicating the degree to which design variables influence performance is codependent on the age group selection and the performance measures investigated. Statistical differences based on insufficient Pr (<0.70) were not indicated.

The isolated effect of player number and pitch size indicate lower player numbers lead to greater acute kinematic and physiological demands in youth ($p \leq 0.05$), but larger pitch size only reliably leads to greater kinematic demands and RPE (Table 29). The influence of SSG bout sequencing on acute core performance demands across all SSG (Table 30), and differentiated by player number and pitch sizes (Table 31) were also reported, alongside the bout effect on V_Z (Table 32) and HR_Z (Table 33). Specific SSG format outcomes for all age categories are presented in Table 34a-e, showing that core performance measures tend to rise with higher relative playing area, notwithstanding outcome and age-specific differences.

Similar results are reported for all cohorts on general performance measures (Appendix 10: Youth SSG general performance measures (imputed values - R)), including V_Z (Appendix 11: Youth SSG relative speed zones (imputed values - R)) and HR_Z (Appendix 12: Youth SSG relative heart rate zones (imputed values - R)) ($p \leq 0.05$). In addition, the effects of playing bouts on general performance measures, V_Z, and $HR_{Z,}$ for all SSG formats demonstrate changes in select outcome measures ($p \leq 0.05$), mostly between Bout 1 and Bout 3 (Appendix 14: Youth SSG formats bout differences – General performance measures (imputed values R), Appendix 15: Youth SSG formats bout differences – Speed zones (imputed values R), and Appendix 16: Youth SSG formats bout differences – Heart rate zones (imputed values R)). Core performance measure values for all SSG formats based on the initial multivariate analysis of complete cases (SPSS), are also available in Appendix 17: Youth SSG core performance measures (complete cases - SPSS). All R-generated non-imputed (complete cases only) results are bundled in and external electronic file, exclusive to this doctoral thesis.

Table 27 SSG format frequencies

		Included SSG (individual bouts)			
		Small	**Medium**	**Large**	**Total**
Pooled	**3v3**	41 (137)	40 (132)	38 (119)	119 (388)
	5v5	20 (80)	20 (60)	29 (87)	63 (227)
	7v7	27 (81)	53 (167)	37 (141)	117 (389)
	Total	88 (298)	113 (359)	104 (347)	305 (1004)
U14	**3v3**	5 (29)	10 (42)	10 (32)	25 (103)
	5v5	0 (20)	10 (30)	0 (0)	10 (50)
	7v7	0 (0)	13 (39)	0 (28)	13 (67)
	Total	5 (49)	33 (111)	10 (60)	48 (220)
U15	**3v3**	6 (18)	6 (18)	6 (18)	18 (54)
	5v5	10 (30)	0 (0)	10 (30)	20 (60)
	7v7	13 (39)	26 (86)	14 (42)	53 (167)
	Total	29 (87)	32 (104)	30 (90)	91 (281)
U16	**3v3**	4 (12)	9 (26)	7 (21)	20 (59)
	5v5	1 (3)	2 (6)	0 (0)	3 (9)
	7v7	4 (12)	4 (12)	5 (15)	13 (39)
	Total	9 (27)	15 (44)	12 (36)	36 (107)
U18	**3v3**	26 (78)	15 (46)	15 (48)	56 (172)
	5v5	9 (27)	8 (24)	19 (57)	36 (108)
	7v7	10 (30)	10 (30)	18 (56)	38 (116)
	Total	45 (135)	33 (100)	52 (161)	130 (396)

Table 28 Multivariate test - Main & interaction effects of youth SSG design variables for overall performance outcomes

EFFECTS		*SPSS*			*R*					
		COMPLETE CASES (186/305 SSG incl.) (636/1004 bouts incl.)			*COMPLETE CASES (186/305 SSG incl.) (636/1004 bouts incl.)*			*IMPUTED CASES (251/305 SSG incl.) (837/1004 bouts incl.)*		
		F	*p*	η^2	F	*p*	η^2	F	*p*	η^2
S	No.	5.55	<0.001*	0.65	4.91	<0.001	0.62	4.14	<0.001	0.47
S	Pitch	4.40	<0.001*	0.59	6.47	<0.001	0.68	6.09	<0.001	0.57
G	Age	2.97	<0.001*	0.50	3.13	<0.001	0.50	3.17	<0.001	0.41
	No.*Pitch	2.14	<0.001*	0.41	2.48	<0.001	0.44	2.08	<0.001	0.31
	No.*Age	3.55	<0.001*	0.54	3.06	<0.001	0.50	1.93	<0.001	0.29
	Pitch*Age	1.58	<0.001*	0.34	1.60	<0.001	0.34	1.40	<0.001	0.23
	No.*Pitch*Age	1.02	0.446*	0.25	1.01	0.450	0.25	1.00	0.495	0.18
B	No.	6.53	<0.001*	0.34	5.89	<0.001	0.31	6.61	<0.001	0.27
O	Pitch	5.88	<0.001*	0.31	7.83	<0.001	0.38	9.01	<0.001	0.34
U	Age	4.34	<0.001*	0.25	5.03	<0.001	0.28	5.87	<0.001	0.25
T	Bout	3.34	<0.001*	0.21	3.54	<0.001	0.22	4.33	<0.001	0.20
	No.*Pitch	2.06	<0.001*	0.14	2.99	<0.001	0.19	2.59	<0.001	0.13
	No.*Bout	1.27	0.015*	0.09	2.92	<0.001	0.18	2.33	<0.001	0.12
	No.*Age	2.76	<0.001*	0.18	1.99	<0.001	0.13	2.13	<0.001	0.11
	Pitch*Age	1.96	<0.001*	0.13	1.14	0.113	0.08	1.06	0.298	0.06
	Pitch*Bout	0.94	0.700*	0.07	1.21	0.044	0.09	1.28	0.011	0.07
	Age*Bout	1.08	0.203*	0.08	1.01	0.460	0.07	1.12	0.101	0.06
	No.*Pitch*Age	1.79	<0.001*	0.12	1.71	<0.001	0.12	1.67	<0.001	0.09
	No.*Pitch*Bout	1.05	0.289*	0.08	1.21	0.008	0.08	1.11	0.092	0.06
	No.*Bout*Age	1.21	0.006*	0.09	1.12	0.063	0.08	0.97	0.681	0.05
	Pitch*Age*Bout	1.30	<0.001*	0.09	1.29	<0.001	0.09	1.36	<0.001	0.07
	No.*Pitch*Age* Bout	1.12	0.067*	0.08	1.10	0.099	0.08	0.90	0.950	0.05

* Observed power a posteriori =1; Non-significant effect=underlined; Youth= (U14+U15+U16+U18); SSG= full small-sided game; Bout = SSG bout (1, 2, 3 averaged); No.= Player No. (3v3, 5v5, 7v7); Pitch= Pitch size (S, M, L); Age= Age category (U14, U15, U16, U18)

Table 29 Influence of SSG (bout) player number and field size on acute core performance demands in youth (Mean ± SD)

	PLAYER NUMBER			PITCH SIZE		
	3v3	***5v5***	***7v7***	***Small***	***Medium***	***Large***
KINEMATIC VARIABLES						
V_{AVG} ($km \cdot h^{-1}$)	5.2 ± 0.9 [AB]	4.8 ± 0.8 [A]	4.8 ± 0.7 [B]	4.6 ± 0.7 [A]	4.8 ± 0.8 [A]	5.4 ± 0.8 [A]
	(5.9 ± 1.0) [ab]	(5.5 ± 1.1) [a]	(5.5 ± 0.9) [b]	(5.1 ± 0.8) [a]	(5.7 ± 0.9) [a]	(6.1 ± 1.1) [a]
HIRD (m)	99.7 ± 68.8 [AB]	71.2 ± 58.4 [A]	53.4 ± 48.0 [B]	36.8 ± 32.3 [A]	81.6 ± 58.1 [A]	100.7 ± 70.2 [A]
	(30.6 ± 27.7) [a]	(22.3 ± 23.0) [a]	(16.2 ± 18.3) [a]	(11.6 ± 13.3) [a]	(25.2 ± 22.7) [a]	(30.6 ± 28.7) [a]
Sprint·min^{-1}	2.0 ± 0.8 [A]	2.0 ± 0.7 [B]	1.9 ± 0.7 [C]	1.9 ± 0.8 [A]	2.0 ± 0.6 [B]	2.0 ± 0.8 [C]
	(2.8 ± 1.2) [a]	(2.7 ± 1.2) [b]	(2.6 ± 1.2) [a]	(2.5 ± 1.2) [a]	(2.8 ± 1.1) [a]	(2.7 ± 1.3) [b]
V_{MAX} ($km \cdot h^{-1}$)	25.4 ± 3.8 [A]	24.9 ± 3.6 [B]	24.2 ± 3.5 [A]	23.2 ± 3.1 [AB]	25.0 ± 3.7 [A]	26.0 ± 3.6 [B]
	(23.1 ± 3.6) [ab]	(22.2 ± 4.2) [a]	(21.7 ± 3.6) [b]	(20.8 ± 3.4) [ab]	(22.8 ± 3.5) [a]	(23.2 ± 3.9) [b]
PHYSIOLOGICAL VARIABLES						
HR_{AVG} (%HR_{MAX})	82.1 ± 4.7 [AB]	77.7 ± 6.9 [A]	77.4 ± 6.8 [B]	79.1 ± 6.5 [A]	78.8 ± 5.9 [B]	80.0 ± 7.0 [C]
	(84.0 ± 6.0) [ab]	(80.6 ± 7.7) [a]	(79.8 ± 8.1) [b]	(81.2 ± 7.6) [a]	(81.5 ± 7.2) [b]	(82.2 ± 7.8) [c]
HR_{MAX} (%HR_{MAX})	95.2 ± 4.3 [AB]	92.4 ± 6.1 [A]	92.4 ± 5.5 [B]	93.1 ± 5.1 [A]	93.3 ± 5.0 [B]	94.0 ± 5.8 [C]
	(92.6 ± 5.6) [ab]	(89.7 ± 7.6) [a]	(89.1 ± 7.2) [b]	(89.9 ± 6.9) [a]	(90.6 ± 6.5) [b]	(91.1 ± 7.2) [c]
HR_{Z5} (≥90%HR_{MAX}) (min)	4.0 ± 3.2 [AB]	2.2 ± 2.5 [A]	2.4 ± 2.8 [B]	3.0 ± 3.3 [A]	2.8 ± 2.7 [B]	3.2 ± 3.0 [C]
	(1.1 ± 1.0) [ab]	(0.7 ± 0.9) [a]	(0.7 ± 1.0) [b]	(0.8 ± 1.0) [a]	(0.8 ± 0.9) [b]	(0.9 ± 1.0) [c]
RPE (6-20)	13.9 ± 2.6 [A]	13.3 ± 2.1 [B]	11.8 ± 2.3 [AB]	12.1 ± 2.5 [AB]	13.1 ± 2.6 [A]	13.6 ± 2.4 [B]
	(12.9 ± 2.6) [a]	(11.9 ± 2.3) [a]	(11.0 ± 2.3) [a]	(11.3 ± 2.6) [a]	(11.8 ± 2.6) [a]	(12.6 ± 2.4) [a]

same grouping letter = significantly **different** ($p \leq 0.05$) across player number/pitch size

Table 30 Influence of SSG bout sequencing on acute core performance demands in youth (Mean ± SD)

	Across SSG FORMATS (3, 5, 7-a-side & S, M, L pitch)		
	Bout 1	***Bout 2***	***Bout 3***
KINEMATIC VARIABLES			
V_{AVG} (km·h^{-1})	5.8 ± 1.1 ^{A}	5.6 ± 0.9 ^{B}	5.6 ± 1.0 ^{A}
HIRD (m)	23.4 ± 26.2 ^{A}	22.6 ± 22.7 ^{B}	23.3 ± 23.5 ^{C}
Sprint·min^{-1}	2.8 ± 1.3 ^{A}	2.6 ± 1.2 ^{B}	2.6 ± 1.1 ^{C}
V_{MAX} (km·h^{-1})	22.2 ± 3.9 ^{A}	22.4 ± 3.8 ^{B}	22.4 ± 3.7 ^{C}
PHYSIOLOGICAL VARIABLES			
HR_{AVG} (% HR_{MAX})	79.9 ± 7.6 ^{AB}	82.6 ± 7.5 ^{A}	82.5 ± 7.3 ^{B}
HR_{MAX} (%HR_{MAX})	89.5 ± 7.0 ^{AB}	91.0 ± 6.9 ^{A}	91.3 ± 6.7 ^{B}
HR_{Z5} (min)	0.6 ± 0.8 ^{AB}	1.0 ± 1.1 ^{A}	0.9 ± 1.0 ^{B}
RPE (6-20)	10.9 ± 2.3 ^{A}	12.1 ± 2.4 ^{A}	12.8 ± 2.6 ^{A}

same grouping letter = significantly **different** ($p \leq 0.05$) across player number/pitch size

155

Table 31 Influence of SSG bout sequencing on acute core performance demands in youth SSG formats and for pitch sizes (Mean ± SD)

SSG format	***3v3 (across S, M, L)***			***5v5 (across S, M, L)***			***7v7 (across S, M, L)***		
	Bout 1	***Bout 2***	***Bout 3***	***Bout 1***	***Bout 2***	***Bout 3***	***Bout 1***	***Bout 2***	***Bout 3***
KINEMATIC VARIABLES									
V_{AVG} (km·h^{-1})	6.1 ± 1.1 ^{A}	5.5 ± 1.2 ^{A}	5.5 ± 1.0 ^{A}	6.0 ± 0.9 ^{B}	5.5 ± 1.0 ^{B}	5.4 ± 0.9 ^{B}	5.7 ± 1.1 ^{AB}	5.5 ± 1.0 ^{C}	5.5 ± 0.9 ^{C}
HIRD (m)	32.1 ± 31.9 ^{A}	20.9 ± 23.0 ^{A}	16.3 ± 18.2 ^{A}	32.1 ± 25.6 ^{B}	21.8 ± 22.4 ^{B}	14.3 ± 15.8 ^{B}	27.5 ± 24.9 ^{C}	24.4 ± 24.1 ^{C}	18.2 ± 20.8 ^{C}
Sprint·min^{-1}	2.9 ± 1.2 ^{A}	2.7 ± 1.4 ^{A}	2.6 ± 1.3 ^{A}	2.8 ± 1.3 ^{B}	2.6 ± 1.2 ^{B}	2.5 ± 1.1 ^{B}	2.6 ± 1.2 ^{C}	2.6 ± 0.9 ^{C}	2.6 ± 1.1 ^{C}
V_{MAX} (km·h^{-1})	22.9 ± 3.9 ^{A}	21.8 ± 3.8 ^{A}	21.8 ± 3.8 ^{A}	23.4 ± 3.3 ^{B}	22.1 ± 4.6 ^{B}	21.5 ± 3.6 ^{B}	22.9 ± 3.5 ^{C}	22.7 ± 4.0 ^{C}	21.7 ± 3.5 ^{C}
PHYSIOLOGICAL VARIABLES									
HR_{AVG} (% HR_{MAX})	82.5 ± 5.8 ^{A}	78.9 ± 7.3 ^{A}	77.8 ± 8.4 ^{AB}	85.4 ± 5.8 ^{A}	81.4 ± 7.9 ^{B}	80.6 ± 8.0 ^{A}	84.2 ± 6.2 ^{B}	81.5 ± 7.8 ^{C}	81.1 ± 7.7 ^{B}
HR_{MAX} (%HR_{MAX})	91.6 ± 5.4 ^{A}	88.7 ± 6.5 ^{A}	87.8 ± 8.1 ^{A}	93.5 ± 5.3 ^{B}	89.8 ± 8.1 ^{B}	89.5 ± 6.8 ^{B}	92.7 ± 5.9 ^{C}	90.8 ± 8.0 ^{C}	90.0 ± 6.5 ^{A}
HR_{Z5} (min)	0.8 ± 1.0 ^{A}	0.4 ± 0.7 ^{A}	0.5 ± 0.7 ^{AB}	1.3 ± 1.1 ^{A}	0.8 ± 1.0 ^{B}	0.8 ± 1.0 ^{A}	1.1 ± 1.0 ^{B}	0.8 ± 0.9 ^{C}	0.8 ± 1.0 ^{B}
RPE (6-20)	11.8 ± 2.3 ^{AB}	10.6 ± 2.0 ^{A}	10.2 ± 2.1 ^{A}	13.3 ± 2.3 ^{A}	12.0 ± 2.0 ^{A}	11.2 ± 2.2 ^{A}	13.6 ± 2.7 ^{B}	13.3 ± 2.2 ^{A}	11.8 ± 2.3 ^{A}
SSG pitch	***Small (across 3v3, 5v5, 7v7)***			***Medium (across 3v3, 5v5, 7v7)***			***Large (across 3v3, 5v5, 7v7)***		
	Bout 1	***Bout 2***	***Bout 3***	***Bout 1***	***Bout 2***	***Bout 3***	***Bout 1***	***Bout 2***	***Bout 3***
KINEMATIC VARIABLES									
V_{AVG} (km·h^{-1})	5.1 ± 0.9 ^{A}	5.8 ± 1.0 ^{A}	6.3 ± 1.1 ^{AB}	5.1 ± 0.8 ^{B}	5.7 ± 0.8 ^{B}	6.0 ± 0.9 ^{A}	5.1 ± 0.7 ^{C}	5.6 ± 0.9 ^{C}	6.0 ± 1.1 ^{B}
HIRD (m)	11.5 ± 13.7 ^{A}	24.1 ± 23.8 ^{A}	32.8 ± 32.0 ^{A}	11.2 ± 13.1 ^{B}	26.9 ± 22.7 ^{B}	27.8 ± 25.5 ^{B}	12.1 ± 13.3 ^{C}	24.7 ± 21.8 ^{C}	31.3 ± 28.2 ^{C}
Sprint·min^{-1}	2.5 ± 1.2 ^{A}	2.9 ± 1.2 ^{A}	2.9 ± 1.4 ^{A}	2.5 ± 1.3 ^{B}	2.7 ± 1.1 ^{B}	2.6 ± 1.2 ^{B}	2.5 ± 1.1 ^{C}	2.7 ± 1.1 ^{C}	2.5 ± 1.1 ^{A}
V_{MAX} (km·h^{-1})	20.7 ± 3.2 ^{A}	22.5 ± 3.6 ^{A}	23.4 ± 4.2 ^{A}	20.9 ± 4.0 ^{B}	23.1 ± 3.5 ^{B}	22.9 ± 3.7 ^{B}	20.8 ± 2.9 ^{C}	22.9 ± 3.5 ^{C}	23.3 ± 3.9 ^{C}
PHYSIOLOGICAL VARIABLES									
HR_{AVG} (% HR_{MAX})	79.6 ± 7.5 ^{A}	80.3 ± 7.2 ^{A}	79.9 ± 8.0 ^{AB}	82.1 ± 7.5 ^{A}	82.0 ± 7.5 ^{B}	83.4 ± 7.5 ^{A}	82.0 ± 7.8 ^{B}	82.0 ± 6.7 ^{C}	83.3 ± 7.3 ^{B}
HR_{MAX} (%HR_{MAX})	88.9 ± 6.6 ^{A}	89.7 ± 6.7 ^{A}	89.7 ± 7.6 ^{A}	90.6 ± 6.7 ^{B}	90.8 ± 6.9 ^{B}	91.6 ± 7.0 ^{B}	90.1 ± 7.4 ^{C}	91.4 ± 5.9 ^{C}	92.0 ± 6.9 ^{A}
HR_{Z5} (min)	0.5 ± 0.8 ^{AB}	0.6 ± 0.8 ^{A}	0.6 ± 0.9 ^{AB}	1.0 ± 1.1 ^{A}	0.9 ± 1.0 ^{B}	1.0 ± 1.1 ^{A}	0.9 ± 1.1 ^{B}	0.8 ± 0.9 ^{C}	1.0 ± 1.1 ^{B}
RPE (6-20)	10.3 ± 2.2 ^{AB}	10.8 ± 2.3 ^{A}	11.5 ± 2.2 ^{AB}	11.7 ± 2.5 ^{A}	11.8 ± 2.4 ^{A}	12.9 ± 2.2 ^{A}	12.1 ± 2.7 ^{B}	12.9 ± 2.6 ^{A}	13.4 ± 2.4 ^{B}

same grouping letter = significantly **different** ($p \leq 0.05$) across player number/pitch size

156

Table 32 Influence of SSG bout sequencing on speed zones in youth (Mean ± SD)

	Across SSG FORMATS (3, 5, 7-a-side & S, M, L pitch)		
	Bout 1	***Bout 2***	***Bout 3***
SPEED ZONES			
V_{Z1} (m)	150.0 ± 26.3 ^{AB}	158.5 ± 24.8 ^{A}	156.2 ± 22.5 ^{B}
V_{Z2} (m)	191.4 ± 65.9 ^{AB}	179.1 ± 55.7 ^{A}	173.5 ± 58.0 ^{B}
V_{Z3} (m)	40.6 ± 30.7 ^{A}	39.7 ± 29.9 ^{B}	41.6 ± 30.2 ^{C}
V_{Z4} (m)	2.6 ± 6.2 ^{A}	2.6 ± 5.9 ^{B}	2.9 ± 7.0 ^{C}
V_{Z5} (m)	0.3 ± 1.9 ^{A}	0.1 ± 0.3 ^{B}	0.1 ± 0.5 ^{C}

same grouping letter = significantly **different** ($p \leq 0.05$) across player number/pitch size

Table 33 Influence of SSG bout sequencing on heart rate zones in youth (Mean ± SD)

	Across SSG FORMATS (3, 5, 7-a-side & S, M, L pitch)		
	Bout 1	***Bout 2***	***Bout 3***
HEART RATE ZONES			
HR_{Z1} (min)	0.2 ± 0.6 ^{AB}	0.1 ± 0.4 ^{A}	0.1 ± 0.4 ^{B}
HR_{Z2} (min)	0.5 ± 0.6 ^{AB}	0.4 ± 0.7 ^{A}	0.4 ± 0.5 ^{B}
HR_{Z3} (min)	0.9 ± 0.8 ^{A}	1.0 ± 0.8 ^{B}	1.0 ± 0.9 ^{C}
HR_{Z4} (min)	1.7 ± 1.0 ^{A}	1.6 ± 1.0 ^{B}	1.6 ± 0.9 ^{C}
HR_{Z5} (min)	0.6 ± 0.8 ^{AB}	1.0 ± 1.1 ^{A}	0.9 ± 1.0 ^{B}

same grouping letter = significantly **different** ($p \leq 0.05$) across player number/pitch size

Table 34a Age category-specific (all youth) core performance measures for specific SSG (bout) formats (Mean ± SD)

YOUTH		Small	Medium	Large
RD (m·min^{-1}) *16/305 SSG missing measurements* *(47/1004 bouts missing measurements)*	**3v3**	82.1 ± 11.6 [A] (91.7 ± 13.3) [a]	83.8 ± 15.8 [AC] (99.1 ± 15.7) [cd]	93.4 ± 15.2 [D] (106.9 ± 19.7) [e]
	5v5	70.8 ± 10.2 [B] (80.1 ± 13.7) [b]	77.5 ± 11.3 [AB] (91.8 ± 13.1) [ac]	85.7 ± 12.4 [ACD] (101.9 ± 17.1) [de]
	7v7	70.6 ± 7.0 [B] (79.0 ± 9.2) [b]	77.2 ± 8.9 [AB] (92.1 ± 15.3) [a]	90.9 ± 10.6 [CD] (97.2 ± 14.4) [acd]
HIRD (m) *30/305 SSG missing measurements* *(101/1004 bouts missing measurements)*	**3v3**	53.5 ± 36.6 [AB] (16.4 ± 15.3) [ab]	104.7 ± 60.5 [C] (32.0 ± 25.2) [d]	144.2 ± 74.7 [E] (45.1 ± 33.4) [e]
	5v5	28.7 ± 20.7 [AB] (10.3 ± 11.3) [ac]	61.8 ± 43.8 [ABCD] (20.2 ± 18.9) [ab]	104.2 ± 63.6 [CDE] (34.2 ± 27.0) [d]
	7v7	20.0 ± 20.4 [A] (5.5 ± 8.4) [c]	69.2 ± 55.1 [BD] (20.9 ± 20.1) [b]	58.1 ± 41.0 [AB] (17.4 ± 18.2) [ab]
Sprint·min^{-1} *16/305 SSG missing measurements* *(47/1004 bouts missing measurements)*	**3v3**	2.0 ± 0.9 [A] (2.7 ± 1.3) [ab]	2.2 ± 0.6 [A] (2.9 ± 1.1) [b]	2.0 ± 0.8 [A] (2.7 ± 1.3) [ab]
	5v5	1.9 ± 0.6 [A] (2.5 ± 1.1) [ab]	2.0 ± 0.5 [A] (2.7 ± 1.0) [ab]	2.0 ± 0.8 [A] (2.8 ± 1.3) [ab]
	7v7	1.7 ± 0.7 [A] (2.3 ± 1.0) [a]	2.0 ± 0.7 [A] (2.7 ± 1.2) [ab]	2.1 ± 0.8 [A] (2.6 ± 1.2) [ab]
V_{MAX} (km·h^{-1}) *16/305 SSG missing measurements* *(47/1004 bouts missing measurements)*	**3v3**	24.6 ± 3.0 [AB] (21.8 ± 3.3) [ab]	25.1 ± 4.5 [AB] (23.4 ± 3.3) [de]	26.6 ± 3.4 [B] (24.3 ± 3.7) [e]
	5v5	22.7 ± 2.7 [AC] (20.4 ± 3.7) [ac]	25.7 ± 3.2 [AB] (22.8 ± 3.5) [bde]	25.9 ± 3.9 [AB] (23.3 ± 4.4) [bde]
	7v7	21.7 ± 2.6 [C] (19.5 ± 2.6) [c]	24.8 ± 3.2 [AB] (22.3 ± 3.7) [bd]	25.4 ± 3.5 [AB] (22.3 ± 3.6) [bd]
HR_{AVG} (% HR_{MAX}) *48/305 SSG missing measurements* *(151/1004 bouts missing measurements)*	**3v3**	81.5 ± 5.5 [ABC] (83.2 ± 6.8) [ab]	82.2 ± 3.7 [BC] (84.2 ± 5.4) [b]	82.6 ± 4.9 [B] (84.8 ± 5.7) [b]
	5v5	77.2 ± 7.2 [ABCD] (79.9 ± 7.9) [ac]	78.6 ± 4.2 [ABCD] (81.9 ± 4.8) [abc]	77.4 ± 8.2 [ACD] (80.5 ± 8.9) [ac]
	7v7	76.8 ± 6.3 [AD] (79.0 ± 8.0) [c]	76.2 ± 6.7 [D] (79.0 ± 8.3) [c]	79.4 ± 7.1 [ABCD] (81.2 ± 8.0) [ac]
HR_{Z5} (min) *52/305 SSG missing measurements* *(166/1004 bouts missing measurements)*	**3v3**	4.3 ± 3.8 [A] (1.1 ± 1.2) [a]	3.9 ± 2.7 [AB] (1.0 ± 0.9) [ac]	3.7 ± 3.1 [AB] (1.1 ± 1.1) [ac]
	5v5	2.2 ± 2.7 [AB] (0.6 ± 0.9) [bc]	2.2 ± 2.4 [AB] (0.7 ± 0.8) [abc]	2.3 ± 2.5 [AB] (0.8 ± 0.9) [abc]
	7v7	1.7 ± 2.0 [B] (0.5 ± 0.8) [b]	2.1 ± 2.6 [B] (0.6 ± 0.9) [b]	3.3 ± 3.2 [AB] (0.8 ± 1.1) [abc]
RPE (6-20) *3/305 SSG missing measurements* *(2/1004 bouts missing measurements)*	**3v3**	13.1 ± 2.8 [AB] (12.5 ± 2.6) [a]	13.7 ± 2.3 [AD] (12.6 ± 2.5) [a]	14.9 ± 2.4 [D] (13.6 ± 2.4) [e]
	5v5	12.4 ± 1.8 [ABC] (11.3 ± 1.7) [bc]	14.3 ± 1.4 [AD] (12.2 ± 2.2) [ab]	13.3 ± 2.5 [ABD] (12.2 ± 2.8) [ab]
	7v7	10.4 ± 1.6 [C] (9.4 ± 1.8) [d]	12.1 ± 2.8 [B] (11.0 ± 2.5) [c]	12.4 ± 1.3 [AB] (12.0 ± 1.6) [ab]

*Same grouping letter = **not** significantly **different** (H_0 not rejected at $p \leq 0.05$);* Highest/lowest

Table 34b Age category-specific (U14) core performance measures for specific SSG (bout) formats (Mean ± SD)

U14		**Small**	**Medium**	**Large**
RD (m·min^{-1})	**3v3**	80.2 ± 5.7 ^{AB}	73.7 ± 25.6 ^{AB}	87.8 ± 22.1 ^{B}
16/305 SSG missing measurements		(88.0 ± 15.1) ^{abc}	(92.0 ± 17.2) ^{ab}	(97.7 ± 26.3) ^{b}
(47/1004 bouts missing measurements)	**5v5**	—	70.0 ± 6.6 ^{A}	—
		(71.2 ± 10.5) ^{d}	(85.0 ± 11.1) ^{ace}	(—)
	7v7	—	68.0 ± 9.7 ^{A}	—
		(—)	(74.8 ± 14.3) ^{de}	(80.2 ± 10.7) ^{cde}
HIRD (m)	**3v3**	26.2 ± 22.2 ^{A}	85.1 ± 44.6 ^{AB}	136.5 ± 117.2 ^{B}
30/305 SSG missing measurements		(8.1 ± 10.0) ^{a}	(24.7 ± 18.0) ^{bc}	(39.8 ± 46.0) ^{c}
(101/1004 bouts missing measurements)	**5v5**	—	55.5 ± 35.2 ^{AB}	—
		(12.6 ± 13.6) ^{ab}	(16.5 ± 15.1) ^{ab}	(—)
	7v7	—	25.9 ± 34.6 ^{A}	—
		(—)	(6.3 ± 10.6) ^{a}	(12.3 ± 12.2) ^{ab}
Sprint·min^{-1}	**3v3**	2.1 ± 0.3 ^{A}	1.9 ± 0.7 ^{A}	1.4 ± 1.1 ^{A}
16/305 SSG missing measurements		(2.5 ± 1.0) ^{a}	(2.3 ± 1.1) ^{ab}	(1.9 ± 1.4) ^{ab}
(47/1004 bouts missing measurements)	**5v5**	—	1.7 ± 0.4 ^{A}	—
		(1.7 ± 0.9) ^{ab}	(2.5 ± 0.8) ^{a}	(—)
	7v7	—	1.2 ± 0.7 ^{A}	—
		(—)	(1.6 ± 0.9) ^{b}	(1.8 ± 0.8) ^{ab}
V_{MAX} (km·h^{-1})	**3v3**	22.9 ± 2.9 ^{AB}	23.6 ± 7.4 ^{AB}	26.5 ± 5.4 ^{B}
16/305 SSG missing measurements		(20.3 ± 2.6) ^{ab}	(23.4 ± 3.4) ^{c}	(23.2 ± 4.7) ^{ac}
(47/1004 bouts missing measurements)	**5v5**	—	25.5 ± 3.2 ^{AB}	—
		(20.4 ± 5.3) ^{abc}	(22.2 ± 3.5) ^{ac}	(—)
	7v7	—	21.2 ± 1.8 ^{A}	—
		(—)	(18.6 ± 2.6) ^{b}	(21.3 ± 3.9) ^{abc}
HR_{AVG} (% HR_{MAX})	**3v3**	81.5 ± 2.5 ^{A}	82.9 ± 6.2 ^{A}	82.2 ± 6.7 ^{A}
48/305 SSG missing measurements		(82.2 ± 8.2) ^{ab}	(82.9 ± 8.3) ^{a}	(84.0 ± 6.7) ^{a}
(151/1004 bouts missing measurements)	**5v5**	—	77.8 ± 4.2 ^{A}	—
		(79.7 ± 5.8) ^{ab}	(81.3 ± 4.7) ^{ab}	(—)
	7v7	—	68.2 ± 6.2 ^{B}	—
		(—)	(70.1 ± 8.4) ^{c}	(77.0 ± 6.3) ^{b}
HR_{Z5} (min)	**3v3**	4.8 ± 3.2 ^{A}	4.1 ± 3.1 ^{A}	2.3 ± 2.6 ^{A}
52/305 SSG missing measurements		(1.0 ± 1.0) ^{a}	(0.8 ± 0.8) ^{a}	(0.6 ± 0.9) ^{ab}
(166/1004 bouts missing measurements)	**5v5**	—	2.3 ± 2.6 ^{A}	—
		(0.4 ± 0.6) ^{ab}	(0.7 ± 0.8) ^{ab}	(—)
	7v7	—	0.1 ± 0.3 ^{A}	—
		(—)	(0.0 ± 0.2) ^{b}	(0.3 ± 0.7) ^{ab}
RPE (6-20)	**3v3**	9.6 ± 0.9 ^{AB}	12.5 ± 2.8 ^{AC}	13.2 ± 2.3 ^{C}
3/305 SSG missing measurements		(9.8 ± 2.4) ^{ab}	(11.0 ± 2.6) ^{ac}	(11.6 ± 1.9) ^{cd}
(2/1004 bouts missing measurements)	**5v5**	—	14.7 ± 1.6 ^{C}	—
		(11.3 ± 1.6) ^{acd}	(12.6 ± 2.2) ^{d}	(—)
	7v7	—	9.3 ± 1.7 ^{B}	—
		(—)	(8.8 ± 1.9) ^{b}	(11.3 ± 2.0) ^{acd}

*Same grouping letter = **not** significantly **different** (H_0 not rejected at $p \leq 0.05$)* Highest/lowest

Table 34c Age category-specific (U15) core performance measures for specific SSG (bout) formats (Mean ± SD)

U15		Small	Medium	Large
RD (m·min^{-1})	**3v3**	98.4 ± 11.3 ^{A}	89.8 ± 9.7 ^{AD}	97.4 ± 7.4 ^{A}
16/305 SSG missing measurements		(98.7 ± 14.2) ^{a}	(91.6 ± 14.7) ^{ac}	(97.9 ± 14.9) ^{a}
(47/1004 bouts missing measurements)	**5v5**	67.6 ± 8.4 ^{BC}	—	83.0 ± 11.3 ^{AD}
		(83.5 ± 13.6) ^{bc}	(—)	(102.5 ± 16.2) ^{a}
	7v7	65.9 ± 6.6 ^{B}	77.8 ± 6.9 ^{CD}	83.1 ± 8.3 ^{AD}
		(74.1 ± 8.6) ^{b}	(97.5 ± 13.3) ^{a}	(97.4 ± 11.0) ^{a}
HIRD (m)	**3v3**	56.6 ± 40.4 ^{ABC}	85.3 ± 75.2 ^{ABC}	108.8 ± 39.9 ^{BC}
30/305 SSG missing measurements		(18.9 ± 17.8) ^{abc}	(28.2 ± 26.7) ^{bc}	(32.6 ± 26.8) ^{bc}
(101/1004 bouts missing measurements)	**5v5**	19.5 ± 12.4 ^{A}	—	115.2 ± 60.7 ^{C}
		(6.3 ± 8.3) ^{a}	(—)	(37.9 ± 25.6) ^{c}
	7v7	30.2 ± 23.8 ^{AB}	79.8 ± 58.5 ^{ABC}	46.8 ± 29.9 ^{AB}
		(8.0 ± 10.8) ^{a}	(23.4 ± 20.1) ^{b}	(14.9 ± 14.3) ^{ab}
Sprint·min^{-1}	**3v3**	2.1 ± 0.3 ^{A}	1.7 ± 0.3 ^{A}	2.0 ± 0.4 ^{A}
16/305 SSG missing measurements		(2.9 ± 0.8) ^{abc}	(2.2 ± 0.6) ^{ac}	(2.4 ± 0.8) ^{abc}
(47/1004 bouts missing measurements)	**5v5**	1.9 ± 0.6 ^{A}	—	2.2 ± 0.6 ^{A}
		(2.8 ± 1.2) ^{ab}	(—)	(3.3 ± 1.0) ^{b}
	7v7	1.5 ± 0.5 ^{A}	2.2 ± 0.5 ^{A}	1.8 ± 0.7 ^{A}
		(1.9 ± 0.7) ^{c}	(3.0 ± 1.1) ^{ab}	(2.6 ± 1.2) ^{abc}
V_{MAX} (km·h^{-1})	**3v3**	24.1 ± 2.6 ^{A}	25.0 ± 3.2 ^{A}	26.9 ± 3.2 ^{A}
16/305 SSGs missing measurements		(21.6 ± 2.9) ^{ab}	(22.6 ± 3.7) ^{ab}	(23.7 ± 4.0) ^{b}
(47/1004 bouts missing measurements)	**5v5**	22.5 ± 2.1 ^{A}	—	25.6 ± 3.4 ^{A}
		(20.1 ± 2.7) ^{a}	(—)	(23.8 ± 3.6) ^{b}
	7v7	23.2 ± 2.9 ^{A}	25.2 ± 2.8 ^{A}	24.9 ± 2.8 ^{A}
		(20.3 ± 3.2) ^{a}	(23.0 ± 3.0) ^{b}	(22.4 ± 3.1) ^{ab}
HR_{AVG} (% HR_{MAX})	**3v3**	87.1 ± 4.0 ^{A}	81.9 ± 4.0 ^{AB}	85.3 ± 6.5 ^{A}
48/305 SSG missing measurements		(88.0 ± 5.4) ^{a}	(83.7 ± 5.3) ^{ab}	(85.3 ± 8.6) ^{ab}
(151/1004 bouts missing measurements)	**5v5**	79.0 ± 5.3 ^{AB}	—	78.7 ± 5.6 ^{AB}
		(82.1 ± 6.9) ^{ab}	(—)	(82.2 ± 5.6) ^{ab}
	7v7	71.4 ± 5.0 ^{B}	76.3 ± 6.1 ^{B}	78.7 ± 7.8 ^{AB}
		(72.2 ± 6.3) ^{c}	(79.6 ± 7.3) ^{b}	(83.0 ± 6.7) ^{ab}
HR_{Z5} (min)	**3v3**	7.8 ± 4.5 ^{A}	3.3 ± 3.1 ^{AB}	4.4 ± 3.7 ^{AB}
52/305 SSG missing measurements		(2.0 ± 1.1) ^{a}	(1.0 ± 1.0) ^{abc}	(1.3 ± 1.2) ^{ab}
(166/1004 bouts missing measurements)	**5v5**	3.1 ± 3.1 ^{AB}	—	2.9 ± 2.8 ^{AB}
		(0.9 ± 1.1) ^{b}	(—)	(0.9 ± 0.9) ^{b}
	7v7	0.2 ± 0.4 ^{B}	2.3 ± 2.6 ^{B}	3.3 ± 3.2 ^{AB}
		(0.1 ± 0.2) ^{c}	(0.7 ± 0.9) ^{bc}	(1.0 ± 1.1) ^{b}
RPE (6-20)	**3v3**	12.7 ± 0.8 ^{A}	12.5 ± 1.2 ^{A}	12.5 ± 2.6 ^{A}
3/305 SSG missing measurements		(12.7 ± 0.9) ^{ab}	(12.1 ± 1.3) ^{ab}	(12.2 ± 1.8) ^{ab}
(2/1004 bouts missing measurements)	**5v5**	12.0 ± 2.3 ^{A}	—	13.9 ± 1.2 ^{A}
		(10.9 ± 1.9) ^{a}	(—)	(13.3 ± 1.2) ^{b}
	7v7	9.3 ± 1.4 ^{B}	12.3 ± 2.9 ^{A}	12.4 ± 0.9 ^{A}
		(8.7 ± 1.9) ^{c}	(11.4 ± 2.4) ^{a}	(12.0 ± 1.1) ^{ab}

*Same grouping letter = **not** significantly **different** (H_0 not rejected at $p \leq 0.05$)* Highest/lowest

Table 34d Age category-specific (U16) core performance measures for specific SSG (bout) formats (Mean ± SD)

U16		Small	Medium	Large
RD (m·min^{-1})	**3v3**	80.8 ± 4.1 ^{AB}	91.2 ± 6.5 ^{AB}	96.0 ± 11.2 ^{AB}
16/305 SSG missing measurements		(93.0 ± 8.2) ^{a}	(110.2 ± 11.8) ^{b}	(115.7 ± 13.8) ^{b}
(47/1004 bouts missing measurements)	**5v5**	85.0 ± N/A ^{AB}	92.0 ± N/A ^{AB}	—
		(96.7 ± 3.8) ^{abc}	(105.3 ± 3.2) ^{abc}	(—)
	7v7	76.2 ± 4.2 ^{A}	87.2 ± 5.4 ^{AB}	101.0 ± 10.1 ^{B}
		(86.1 ± 7.1) ^{a}	(94.4 ± 13.3) ^{ac}	(109.3 ± 14.6) ^{bc}
HIRD (m)	**3v3**	68.0 ± 33.9 ^{ABC}	131.7 ± 58.1 ^{BC}	158.7 ± 53.2 ^{B}
30/305 SSG missing measurements		(22.0 ± 18.3) ^{abc}	(39.5 ± 29.5) ^{bc}	(49.9 ± 28.1) ^{c}
(101/1004 bouts missing measurements)	**5v5**	36.0 ± N/A ^{ABC}	27.0 ± N/A ^{ABC}	—
		(12.0 ± 10.6) ^{abc}	(8.7 ± 0.6) ^{ab}	(—)
	7v7	9.0 ± 7.8 ^{A}	52.0 ± 34.6 ^{ABC}	43.8 ± 21.9 ^{AC}
		(2.9 ± 3.2) ^{a}	(17.1 ± 13.2) ^{ab}	(14.0 ± 13.6) ^{a}
Sprint·min^{-1}	**3v3**	1.1 ± 1.3 ^{A}	2.6 ± 0.4 ^{B}	2.2 ± 1.2 ^{AB}
16/305 SSG missing measurements		(1.6 ± 1.7) ^{a}	(3.9 ± 0.8) ^{c}	(3.1 ± 1.6) ^{bc}
(47/1004 bouts missing measurements)	**5v5**	2.0 ± N/A ^{AB}	2.6 ± N/A ^{AB}	—
		(2.9 ± 0.5) ^{abc}	(3.8 ± 0.4) ^{abc}	(—)
	7v7	1.9 ± 1.4 ^{AB}	1.5 ± 1.1 ^{AB}	2.1 ± 1.4 ^{AB}
		(2.5 ± 1.7) ^{ab}	(2.0 ± 1.4) ^{ab}	(2.7 ± 1.8) ^{ab}
V_{MAX} (km·h^{-1})	**3v3**	23.2 ± 1.8 ^{A}	25.6 ± 3.1 ^{A}	26.5 ± 2.1 ^{A}
16/305 SSG missing measurements		(20.9 ± 2.6) ^{ab}	(23.3 ± 3.0) ^{b}	(24.6 ± 2.8) ^{b}
(47/1004 bouts missing measurements)	**5v5**	21.5 ± N/A ^{A}	20.3 ± N/A ^{A}	—
		(19.8 ± 1.9) ^{ab}	(20.0 ± 0.3) ^{ab}	(—)
	7v7	20.3 ± 0.7 ^{A}	24.7 ± 3.5 ^{A}	25.0 ± 3.7 ^{A}
		(19.1 ± 1.5) ^{a}	(22.3 ± 3.5) ^{ab}	(21.9 ± 3.8) ^{ab}
HR_{AVG} (% HR_{MAX})	**3v3**	77.7 ± 4.7 ^{A}	81.9 ± 2.1 ^{A}	83.1 ± 2.7 ^{A}
48/305 SSG missing measurements		(81.4 ± 4.7) ^{a}	(85.0 ± 2.9) ^{a}	(86.1 ± 3.5) ^{a}
(151/1004 bouts missing measurements)	**5v5**	82.8 ± N/A ^{A}	81.8 ± N/A ^{A}	—
		(85.2 ± 3.2) ^{a}	(85.9 ± 2.0) ^{a}	(—)
	7v7	77.6 ± 2.7 ^{A}	75.5 ± 2.5 ^{A}	81.5 ± 4.4 ^{A}
		(80.1 ± 3.6) ^{a}	(78.3 ± 5.4) ^{a}	(83.2 ± 5.3) ^{a}
HR_{Z5} (min)	**3v3**	1.7 ± 2.4 ^{A}	4.4 ± 2.6 ^{A}	5.4 ± 2.7 ^{A}
52/305 SSG missing measurements		(0.6 ± 0.8) ^{abc}	(1.3 ± 0.8) ^{ac}	(1.6 ± 1.1) ^{c}
(166/1004 bouts missing measurements)	**5v5**	3.6 ± N/A ^{A}	4.3 ± N/A ^{A}	—
		(0.9 ± 1.1) ^{abc}	(1.4 ± 0.9) ^{abc}	(—)
	7v7	1.1 ± 1.1 ^{A}	0.2 ± 0.2 ^{A}	3.3 ± 3.7 ^{A}
		(0.3 ± 0.7) ^{ab}	(0.1 ± 0.1) ^{b}	(0.9 ± 1.0) ^{abc}
RPE (6-20)	**3v3**	13.0 ± 2.2 ^{AB}	13.6 ± 2.2 ^{AB}	16.3 ± 1.1 ^{B}
3/305 SSG missing measurements		(12.4 ± 1.9) ^{ab}	(12.9 ± 2.2) ^{b}	(14.8 ± 2.1) ^{c}
(2/1004 bouts missing measurements)	**5v5**	12.0 ± N/A ^{AB}	14.0 ± 1.4 ^{AB}	—
		(11.0 ± 1.0) ^{ab}	(11.3 ± 2.6) ^{ab}	(—)
	7v7	11.0 ± 1.4 ^{A}	14.2 ± 2.1 ^{AB}	12.0 ± 1.2 ^{A}
		(10.0 ± 1.5) ^{a}	(11.7 ± 2.4) ^{ab}	(11.5 ± 1.6) ^{ab}

Same grouping letter = ***not*** *significantly* ***different*** *(H_0 not rejected at $p \leq 0.05$)* Highest/lowest

Table 34e Age category-specific (U18) core performance measures for specific SSG (bout) formats (Mean ± SD)

U18		Small	Medium	Large
RD (m·min⁻¹)	**3v3**	79.4 ± 11.0 A	83.8 ± 9.6 ABC	93.9 ± 14.9 BC
16/305 SSG missing measurements		(91.5 ± 12.7) ab	(102.4 ± 11.5) d	(111.5 ± 15.6) f
(47/1004 bouts missing measurements)	**5v5**	73.4 ± 11.3 A	87.7 ± 7.2 ABC	87.1 ± 13.0 ABC
		(81.4 ± 13.1) ac	(100.7 ± 9.8) bdef	(101.5 ± 17.7) de
	7v7	74.4 ± 3.7 A	80.3 ± 7.2 AB	94.3 ± 8.3 C
		(82.5 ± 7.3) c	(92.5 ± 9.7) abce	(102.3 ± 10.7) d
HIRD (m)	**3v3**	57.6 ± 37.7 AB	107.9 ± 62.9 BC	153.2 ± 73.1 C
30/305 SSG missing measurements		(18.6 ± 15.3) a	(35.0 ± 25.9) c	(50.1 ± 29.4) d
(101/1004 bouts missing measurements)	**5v5**	40.7 ± 25.7 AB	78.2 ± 57.3 ABC	98.2 ± 66.0 BC
		(13.5 ± 11.8) ab	(29.4 ± 23.5) ac	(32.1 ± 27.8) c
	7v7	10.2 ± 9.5 A	83.5 ± 51.2 B	69.4 ± 48.6 AB
		(3.1 ± 3.8) b	(27.2 ± 22.4) ac	(22.5 ± 22.5) ac
Sprint·min⁻¹	**3v3**	2.1 ± 1.0 A	2.2 ± 0.4 A	2.2 ± 0.4 A
16/305 SSG missing measurements		(2.9 ± 1.4) a	(3.2 ± 0.7) a	(3.0 ± 1.0) a
(47/1004 bouts missing measurements)	**5v5**	1.9 ± 0.6 A	2.3 ± 0.2 A	1.9 ± 0.9 A
		(2.7 ± 1.0) a	(2.9 ± 1.2) a	(2.5 ± 1.4) a
	7v7	2.0 ± 0.4 A	2.2 ± 0.4 A	2.2 ± 0.6 A
		(2.7 ± 0.7) a	(3.0 ± 0.9) a	(3.0 ± 1.0) a
V_{MAX} (km·h⁻¹)	**3v3**	25.2 ± 3.2 A	25.8 ± 3.1 A	26.7 ± 2.8 A
16/305 SSG missing measurements		(22.6 ± 3.6) a	(23.7 ± 3.4) ac	(25.0 ± 3.2) c
(47/1004 bouts missing measurements)	**5v5**	23.2 ± 3.6 AB	26.9 ± 2.4 A	26.0 ± 4.2 A
		(21.0 ± 3.6) ab	(24.3 ± 3.4) ac	(23.1 ± 4.7) ac
	7v7	20.2 ± 1.4 B	27.0 ± 2.7 A	25.8 ± 4.0 A
		(18.8 ± 1.6) b	(23.8 ± 4.1) ac	(22.7 ± 3.9) a
HR_{AVG} (% HR_{MAX})	**3v3**	80.6 ± 5.7 A	82.0 ± 2.9 A	81.6 ± 4.1 A
48/305 SSG missing measurements		(82.7 ± 6.4) ab	(84.8 ± 3.6) a	(84.5 ± 4.7) a
(151/1004 bouts missing measurements)	**5v5**	74.4 ± 8.8 A	79.1 ± 4.5 A	76.6 ± 9.5 A
		(76.3 ± 9.8) c	(82.2 ± 5.0) abc	(79.7 ± 10.1) bc
	7v7	81.9 ± 3.0 A	81.6 ± 2.4 A	79.5 ± 7.4 A
		(85.1 ± 4.4) a	(84.7 ± 4.2) a	(81.3 ± 9.3) abc
HR_{Z5} (min)	**3v3**	3.8 ± 3.7 A	3.6 ± 2.7 A	3.4 ± 3.1 A
52/305 SSG missing measurements		(1.0 ± 1.2) a	(1.0 ± 0.9) a	(1.0 ± 1.1) a
(166/1004 bouts missing measurements)	**5v5**	1.1 ± 2.0 A	1.7 ± 2.4 A	2.0 ± 2.3 A
		(0.3 ± 0.7) a	(0.6 ± 0.8) a	(0.7 ± 0.9) a
	7v7	3.3 ± 2.0 A	3.7 ± 2.7 A	3.2 ± 3.3 A
		(1.1 ± 0.9) a	(1.1 ± 1.0) a	(0.9 ± 1.1) a
RPE (6-20)	**3v3**	13.9 ± 2.9 AB	15.0 ± 1.6 AD	16.1 ± 1.6 D
3/305 SSG missing measurements		(13.4 ± 2.4) ab	(14.2 ± 2.2) ae	(15.0 ± 1.8) e
(2/1004 bouts missing measurements)	**5v5**	12.9 ± 0.9 ABC	13.9 ± 1.1 ABCD	13.1 ± 3.0 ABC
		(11.9 ± 1.6) c	(12.1 ± 2.1) bc	(11.6 ± 3.2) c
	7v7	11.5 ± 0.8 C	13.7 ± 1.2 ABCD	12.5 ± 1.5 BC
		(10.0 ± 1.7) d	(12.6 ± 1.6) bc	(12.3 ± 1.6) c

*Same grouping letter = **not** significantly **different** (H_0 not rejected at $p \leq 0.05$)* Highest/lowest

7.4 Discussion

To date, no study has clarified the isolated and combined influence of the essential design elements of SSG^{RU} on performance measures, using a standardised approach. The influence of player number and pitch size on SSG outcomes have been explored for various conditions in both RU and RL, albeit using univariate analyses for individualised measures such as HR, TD, RPE, pass and catch proficiency, alongside other skills [56, 87, 88, 209]. In addition to these analytical perspectives for limited outcome measures, this study provides a multifactorial and unifactorial perspective on SSG design in RU, describes the characteristics of SSG^{RU} in youth, and documents the nuances within and between age groups. This holistic reference frame can serve as a guide for practitioners, who have been documented to pursue various performance outcomes simultaneously in different age categories [349].

This investigation showed that the individual elemental design factors player number, field size, age category, and bout sequence significantly impact SSG performance (p<0.001), accounting for up to 65% of the variance in performance (Table 28). Furthermore, these design factors' impact on SSG performance is dependent on their combination. Performance measures, i.e. outcome variables, also require consideration when designing and evaluating SSG, as the effect of design factors is dependent on the inclusion or exclusion of specific outcome variables, and differentially so for different age groups. Player number and pitch size exert the greatest influence to raise or lower kinematic, physiological, and physical demands by increasing or decreasing relative playing area.

7.4.1 The importance of SSG design factors: a multivariate perspective

By design, SSG require the essential variables of player number and pitch size to be applied for one or more bouts to any specific age category. The first and main aim of the multivariate analyses in our study (Table 28), was to quantify the importance of these elemental design factors with respect to their relative effect on SSG performance, by clustering a large array (52) of outcome metrics, commonly used in youth SSG^{RU}. Our data showed that, dependent on the model considered, between 47% and 65%, 57% and 68%, and 41% and 50% of the variance in SSG performance is accounted for by player number, field size, and age category, respectively, when playing three four-minute bouts. Considering the differences between the models (F-value, Table 28), player number and field size seem to have a similar impact on the variance in the means between the different SSG formats, for the combined kinematic, physiological, and physical outcome variables. When active recovery was excluded from the analysis, these design factors' influence was also greater (34% and 31%) to that of player age (25%) and bout sequence (21%).

Chronological age is nevertheless a differentiating factor, meaning performance outcomes can differ between age groups. This differential execution of the same SSG formats between different age groups is evident despite accounting for the remaining elemental design factors. Consequently, SSG design should be considered within narrow and specific age categories. In line with this observation, Gabbett and colleagues found greater distance, velocity, and high intensity-related measures for senior RL players compared to juniors [56].

It is important to recognise that relative age effects (RAE) act as a hidden variable and play a considerable role in rugby performance, leading to an overrepresentation of early-mature players [403-405]. This mismatch between age classification and biological maturation can hamper youth players' development and needs to be considered as an underlying factor in SSG^{RU} performance differences. Preliminary research in U16 and U18 RU youth suggested that age categorisation might yield a performance mismatch in SSG-related training, as cluster analysis by training performance variables such as TD, V_Z, number of impacts, and HR, showed a 57% and 43% partition across all players [306]. Four U18 and one U16 players were thereby "mismatched", relative to their age group. Of note is that the limited sample size in this study (n U16=13,n U18=15) and the fact that training targets and content were not standardised, requires reservation about the conclusions.

In addition to age, performance variability between players is related to playing experience, talent, and playing position [89, 406-408]. One study found "better" SSG performances by experienced senior players versus novices. However, this was for select outcome measures only, as no differences were observed in physical variables, in contrast to superior technical and tactical predictors, such as tries, tackles, and passes made [89]. Chronologically older players will generally have greater training and playing experience, and additionally be a product of the selection bias based on RAE [403, 405, 408, 409].

Players with greater biological maturation demonstrate superior anthropometric characteristics in rugby, which can contribute to speed, power, and momentum-related game components [404, 405]. Improvements in these physical qualities are also observed with greater training age [408]. However, these changes occur non-linearly and are dependent on the specific quality and test used. For example, strength assessment through back squat and prone row showed clear annual improvements that were greater in academy players with 0 and 2 years than those with 1 year of formalised training experience [408]. Novel training stimuli and cumulative training proficiency are likely to play an important role in this. Conversely, sprint speed improvements were documented to be less distinct when differentiating by training age. However, when 10-m sprint times were combined with body mass, momentum improvements were more pronounced [408].

Regardless of the nuances, annual improvements in specific endurance, strength, and power output coincide with anthropometrical development, across training ages in academy rugby players [405, 408]. Training age is therefore likely a function of chronological age, biological maturity, training experience, and inherent inter-player variability [408]. These observations provide an explanation for why our large data pool suggests up to 50% of the variance between SSG formats can be attributed to differences in chronological age categorisations. Notwithstanding the former evidence, the exploration of SSG performance as a proxy-measure for youth player evaluation and differentiation may nevertheless be conceptually interesting because of its practical feasibility. In addition to these analytical perspectives for limited outcome measures, the current multivariate approach provides a holistic reference frame within which innate characteristics of GBT can be applied generally, as practitioners pursue various performance outcomes simultaneously in different age categories [349].

The age stratification and performance outcome grouping in the extended results (Appendix 13: Youth SSG age cohorts multivariate tests (complete cases - SPSS)), in addition to Table 28, indicate that alongside age categorisation, metric selection itself warrants the utmost specificity; i.e., (1) pooled vs. non-pooled age, and (2) comparison of non-identical performance metrics can directly impact the differential effects of the other SSG design factors. For example, any design combination of 3, 5, or 7-a-side on a S, M, or L pitch, for 1, 2, or 3 bouts does not significantly affect the outcome of overall performance for *"adolescents".* Such broad age bands are sometimes applied to SSG research [209, 382]. However, this exact design choice becomes relevant when considering more specified age groups, such as [U14/U15] and [U16/U18], and U15 individually, but not for U14 (Appendix 13: Youth SSG age cohorts multivariate tests (complete cases - SPSS)). In turn, while a specific combination of pitch size, player number, and bout sequencing matters significantly for overall performance outcomes in U18, this is not the case when solely considering TD in V_Z. These results show that broad age bands and general or generically labelled metric grouping provide a less granular perspective, potentially confounding specific performance differences.

The results for U14 furthermore suggest a threshold age, prior to which the design of SSG has a smaller impact on performance. This could be due to differences in cognitive, psychosocial, and socio-affective factors between early versus middle and late-adolescent developmental stages [410]. Early adolescents (~10-13 years) can understand the basic concepts underlying sport-play and start remembering complex strategies. Concomitantly, prepositional logic, analytic, and problem-solving abilities begin to arise.

However, peer-comparison and peer and adult influences, a predominant preoccupation with bodily concerns (e.g., unease and discomfort), and success experience play an important role at this stage 410. As the SSG were standardised without real-time feedback, coaching, or motivating, these cognitive, psychosocial, and socio-affective discrepancies with older age groups, in addition to the physical differences, may translate to a more limited game-play. A lower ability to think abstractly, have a consistent overarching drive, strategise for optimal performance, and utilise the differentially available possibilities between SSG formats, may have contributed to a more uniform execution across SSG. Further to that, an essential aspect of SSG for younger players is fun experience [172, 173, 391]. Since more extreme formats (e.g., 3v3 L or 7v7 S) may be perceived as less fun, this could play a role in U14 SSG execution.

Across all youth, the significance of the interaction between player number, pitch size, and age changes for full SSG compared to bouts (Table 28). Furthermore, between specific age categories differences can be observed regarding the interaction between bout and other design factors (e.g., pitch*bout U14 = U15 ≠ U18 = pooled) (Appendix 13: Youth SSG age cohorts multivariate tests (complete cases - SPSS)). These differences seem to indicate that standardised recovery instructions were carried out differently between different age groups, and that the effect of bout sequencing impacted players differently at different ages. In line with this, limited kinematic and physiological SSG outcomes (TD and Stagno's TRIMP) have been shown to differentially change depending on the bout, in professional players [345]. Considering SSG training can replicate match peak movement demands, but most of a SSG^{RU} training session time is spent at 30 to 39% of those peak intensities [346], programming of SSG training should be done with the elemental high-intensity building blocks, (i.e., SSG bouts), in mind to optimise training outcomes.

The combined results in Table 28 and (Appendix 13: Youth SSG age cohorts multivariate tests (complete cases - SPSS)), regarding the magnitude and significance of the main and interaction effects of SSG player number and pitch size, across subgroups, suggest that player number is the main driving factor, especially for U18. This preliminary indication might be underpinned by tactical reasons, such as the ability to have more interpersonal interactions, create more complex positional structures and have more ball passing options [84, 183, 298, 411]. At an older age, players may be more capable to capitalise on these opportunities given their superior cognitive abilities, functional capacity, and fully developed perceptual motor abilities [410]. Such observations speak to the importance of specificity within SSG design, both in terms of age categories and performance measures considered.

As most RU practitioners operate on the youth level [349], it is important to take into account their current in-practice categorisation. Ultimately, the analyses of the SSG design factors revealed that all elemental design variables contribute to the outcome of SSG performance, while being codependent to a large degree. Thus, mutual interactions need to be considered, as one factor can modulate another factors' influence.

In practice, SSG format design requires player number and pitch size to jointly be the primordial consideration from a per-bout-perspective, to create a suitable relative playing area in function of one or more individually evaluated kinematic, physiological, or physical outcome metrics. As players of different ages could respond differently to SSG formats (player number*pitch size), SSG should be designed for targeting a specific age group and re-evaluated for efficacy when applying to a different cohort. The use of bouts can be considered to optimise the targeted measures, subservient to these first three design factors while safeguarding the function of recovery.

7.4.2 Player number and pitch size: a univariate approach

As the multivariate approach showed that elemental design factors, and player number and pitch size in particular, influence overall SSG performance outcomes, the univariate analyses clarified the specific effects of these main drivers on the core performance measures, individually (Table 29). When pitch size is accounted for, the lowest player numbers (3v3) elicited the greatest kinematic and physiological demands. Larger pitches, when accounting for player number, showed incrementally greater kinematic demands, but not for sprints rate. Of note is that these changes did not occur proportionally; three-a-side and small pitches seem to entail a threshold that differs consistently across most core performance measures, whereas the other formats might not mutually differ.

In contrast, distance-related metrics like V_{AVG} and HIRD were observed to respond linearly to scaling (i.e., doubling the playing area). Apart from RPE, which was higher on a medium and large pitch, pitch size did not significantly influence physiological demands. It is important to account for SSG structure, as average bout values result in more prominent differences between formats in terms of player number and pitch sizes. The inclusion of active recovery masked effective differences in HIRD, sprint rate, V_{MAX}, and RPE during the work bouts. A clear takeaway from these observations is that 3v3 on a large pitch (583 m^2), and thus maximising relative playing area, elicits the greatest kinematic and physiological demands in RU adolescents.

Kennett et al. (2012) reported similar observations in semi-professionals (21.3 ± 6 1.2 years), with greater kinematic demands for less players when comparing two or more formats (4, 6, 8-a-side), depending on the outcome measure. Greater kinematic demands were also found for larger pitches (S/L). Sprints were thereby higher in 4v4 vs 8v8 and for L vs S pitch, unlike in our results. Parallel to our observations, no differences were reported in HR outcomes for pitch sizes. However, player numbers also had no effect. In contrast to our findings, RPE was higher for lower player numbers and on a small pitch [88].

Of note is the higher cardiovascular load (~87-89 %HR_{MAX}) reported by Kennett and colleagues compared to our results (~77-82 %HR_{MAX}). The noted discrepancies with our observations are likely due to one or more confounding elements, such as a different RU substratum (male semi-professional seniors), non-identical touch rules, non-randomised allocation, the influence of encouragement, divergent sprint definitions (i.e., no acceleration component), and moreover, the differences in SSG design (2x9 min, 32x24 m and 64x48m). In addition, previous research has indicated that higher-level opposition in SSG can lead to greater cardiovascular and kinematic workloads [291]. Contributing environmental factors (e.g., playing surface, climatological conditions) could also play a role but have not been well-investigated in rugby and are often not specified [97]. The combination of these potentially confounding factors limits the ability to isolate causal mechanisms that pinpoint singular effects of design factors on specific SSG performance metrics, across and between studies.

In similar SSG^{RU} research, multiple univariate analyses showed significant design effects and interactions for various formats; i.e.,1v1 vs 2v1 vs 7v7 on different pitches and with different rules [87]. Differences were reported between V_Z and between impact zones mutually, with more distance and impacts occurring in lower zones for all SSG. In line with our research, no HR-related differences were found. The analyses within this study design confounded basic design elements with differing playing rules, which have been demonstrated in SSG^{RU} to influence physical demands by themselves, hampering the ability to detect direct relationships between outcome measures and constituent design variables [283].

The comparisons made are informative, yet do not provide a definitive distinguishment between SSG formats for basic design elements. Nevertheless, the different SSG designs elicited differential outcomes, with cardiovascular demands that were uniformly higher than in the current study (~23-27% vs ~12-22% of time >90% HR_{MAX}) [87]. As with Kennett and colleagues, confounding elements like coaching and encouragement, a senior professional context, and different playing rules are likely of influence.

To date, no RU-specific data is available for adolescents, but in line with our observations, elite U16 RL players showed significantly higher HR_{AGV} in the smallest format (4v4 vs 6v6) and no differences were noted for pitch sizes (S-M-L) [209]. Of note is that U13 did not show any differences between formats, which would speak to the influence of age, as established in the current investigation. Further to that, RL juniors have been documented to cover less distance at moderate, high, and very-high intensities, and more distance at low and very-low intensities than seniors where identical 8v8 “off side” rule constraints were applied on a S (10x40 m) or L (40x70 m) pitch [56]. Juniors saw greater TD, RD, moderate, high, and VHIRD on a large pitch, whereas seniors also saw greater very low-intensity distance but not VHIRD. These greater kinematic demands converge with our findings of the highest V_{AVG} and HIRD on the largest pitch. Juniors also had more short recoveries between efforts and less moderate and long recoveries than seniors, except for on the large pitch [56]. In preadolescent youth (U9), Thomas and Wilson showed that less structured games in the form of reduced player number, set pieces, and specialised skills resulted in 25% more ball-in-play, leading to approximately double the successful passes and tries, and 55% more runs with the ball [173]. These nuances regarding age, SSG design, and outcomes highlight the importance of basic design factors and cohort specificity, in addition to the specificity of performance measurement.

Other design-related SSG^{RU} studies have focussed on technical, tactical, and physical components. For example, specific formats such as 1+1 vs 1 can be superior to others for optimising passing skill-acquisition in university-age novices [350] and integrated load ratios can be reliable to assess adolescents’ aerobic fitness [344]. Most technical, tactical, and physical SSG characteristics can be kept consistent with minimal variability across playing bouts and days, while position-specific SSG can target physical and technical characteristics differentially (higher TD, accelerations/decelerations, Stagno’s TRIMP, relative get-ups, but lower HSRD) compared to generalised SSG in professional players [345, 347, 348]. These studies further exemplify the importance of managing design factors, but their methodology limits within and cross-study comparisons of the effects of player number and pitch size, in isolation. Nevertheless, Zanin and colleagues argued that reduced pitch dimensions and relative playing area impacted HSRD negatively [345].

In summary, our observations are congruent with the current understanding that training outcomes can be targeted by manipulating SSG design variables, most prominently player number and pitch size [97]. Our findings suggest that in RU school-level adolescents, lower player numbers and larger pitch sizes can effectively maximise distance, speed, and acceleration-related metrics, as well as perceived exertion. Maximal cardiovascular stimulation requires minimising player numbers.

To effectively elicit the highest SSG demands, minimal thresholds regarding player number and pitch size might exist; 3v3 and large pitches seem most effective for maximising core performance outcomes.

7.4.3 Youth small-sided game performance

7.4.3.1 Responses to small-sided game structure

Small-sided games versus elemental playing bouts

As can be expected, performance measures normalised for time show that playing intensity is generally higher for average bouts than for whole SSG (e.g., Table 29; Table 34a; & Appendix 10: Youth SSG general performance measures (imputed values - R)). This is logical due to the incorporation of active rest intervals. An exception therein was RPE, as Bout 3 values were used for full SSG. However, this trend is not universal across performance measures and SSG formats. Of note is that relative walking distance (V_{Z1}) was similar for SSG and bouts (Appendix 11: Youth SSG relative speed zones (imputed values - R)). For example, across all youth, 3v3-S resulted in ~39 m·min^{-1} for both SSG and the average bout, where 3v3-L was alike (both ~37 m·min^{-1}). All other formats gave similar results (e.g., 7v7-S: ~39 and 40 m·min^{-1}, respectively). Considering the instruction for active recovery was light jogging, these results indicate that compliance among adolescents was suboptimal. Methodological interference in the form of a minimal amount of slow walking (as short-term standing still would not have added distance) for RPE collection, could have had a minor influence.

Further to that, jogging and walking distance were similar for various formats; e.g., 3v3-S and 3v3-L V_{Z2} was ~39 and ~44 m·min^{-1}. However, more jogging occurred during working bouts than during full SSG, and compared to bout walking distance; e.g., ~45 vs ~39 m·min^{-1} (3v3-S) and ~52 vs ~37 m·min^{-1} (3v3-L). Further to that, across formats, there is a clear trend of an increasingly greater discrepancy for RD to be higher for bouts than for SSG, as V_Z increases (Appendix 11: Youth SSG relative speed zones (imputed values - R)). This observation is in line with most performance measures. Consequently, these results show that very-low speed locomotion is alike whether considering SSG or bouts, but it seems more feasible to assess performance-determining higher-speed locomotion based on the actual working bouts.

A side-by-side age group comparison of performance measures demonstrates certain trends, like with V_Z, showing unequivocally that most distance is covered at low relative speeds (V_{Z1} and V_{Z2}), with increasingly lower distances in higher speeds bands, irrespective of the format or age (Appendix 11: Youth SSG relative speed zones (imputed values - R)). Notwithstanding, clear unidirectional trends between age groups regarding structure are not evident; V_{Z1}-to-V_{Z2} proportions for SSG and bouts, as well as SSG-to-bout relative values, are specifically dependent on the format (player number and pitch size) and vary between age groups. For example, when considering all youths' individual playing bouts, the data showed more jogging (V_{Z2}) than walking (V_{Z1}), except for 5v5-S and 7v7-S. This observation suggests a tipping point exists of around 87.5 $m^2 \cdot player^{-1}$, below which SSG formats become too populated to inherently incentivise running. Notwithstanding this general notion across all age groups, and it being fully concurrent with U14, and to a lesser degree with U15 results, it is counter to U16's 5v5-S (V_{Z1}/V_{Z2} = ~160/188 m) and U18's 7v7-S (V_{Z1}/V_{Z2} = ~154/161 m) that did not see more walking than jogging for those specific formats.

Further to the nuance regarding age and SSG structure, the highest exposure to optimal cardiorespiratory intensity (≥90% HR_{MAX}) was seen in 3v3-S, making it most suited for match conditioning. Differences between age groups were large, however; from 18 minutes, U14, U15, U16, and U18 respectively, spent 4.8 ± 3.2 (~27%), 7.8 ± 4.5 (~43%), 1.7 ± 2.4 (~9%), and 3.8 ± 3.7 (~21%) in HR_{Z5} (Appendix 12: Youth SSG relative heart rate zones (imputed values - R)). The highest exposure for U16 (5.4 ± 2.7 min; ~30%) was found in 3v3-L, contrasting the other three age groups. Relative to working bouts, these age groups spent 1.0 ± 1.0, 2.0 ± 1.1, 0.6 ± 0.8, and 1.0 ± 1.2 minutes in HR_{Z5}, respectively 25%, 50%, 25%, and 40% of full-time. The different ratios of SSG-to-bout utilisation for different age groups are evidence of age-specific work and recovery, in which work bouts were generally completed with more cardiorespiratory intensity, but not always (cf. U14 HR_{Z5} 27% / 25%). Such between-age group differences and relative SSG-to-bout proportions are evident throughout the data, demonstrating that differentiation is warranted in function of the target population and selection of adequate measures for the targeted goal.

In summary, it is important to recognise overall trends can be found when evaluating the structure of GBT across performance measures in adolescent RU players. By and large, working bouts are characterised by higher intensity than whole SSG. However, differentiation between age groups and performance metrics is necessary to optimise GBT, as the execution of standardised work bouts and active recovery phases can vary between age groups and for selected metrics. The SSG period in which these are considered can furthermore confound the targeted load of the work bout, when not accounted for. Practitioners should be cognisant of this observation. It is advisable to be consistent when evaluating SSG training, whether pursuing specific targets within a structure that more closely resembles full matches with the inclusion of low-intensity periods (i.e., SSG), or whether "worst-case scenarios" at maximal intensity are targeted (i.e., bouts).

Practically, bouts can be viewed as short SSG, used as elementary building blocks to maximise high-intensity efforts and reduce pacing strategies [393]. Of note, when matched for format and duration, this strategy may only be significantly more effective at increasing selective kinematic efforts (e.g., HSR but not TD) for a limited number of short-duration bouts, and not necessarily for physiological responses (e.g., HR, blood lactate, RPE) [393, 412]. However, various, SSG structures (e.g., 24 continuous, 3x8, and 4x6 min) can maximise time at optimal conditioning intensity (≥90% HR_{MAX}) [393]; therefore SSG structure appears malleable to target specific goals. Our data suggests such structural plasticity might be needed to optimise time at target intensity for certain age groups more than others.

Bout sequencing

When it comes to bout-sequencing, the core performance values across all youth and SSG formats indicate a contrast between Bout 1 and one or more subsequent bouts (Table 30). Bout-stacking affects physiological measures more than kinematic outcomes, as HR and RPE rises while movement outcomes stay the same, notwithstanding a small decrease in V_{AVG}. In the case of categorised performance measures, similar observations were made whereby Bout 1 was distinct from Bout 2 and Bout 3. For example, following Bout 1, players walked and jogged more, yet concurrently spent less time in HR_{Z1} and HR_{Z2}, and more time in HR_{Z5} (Table 32 and Table 33). These polar-opposite HR observations speak to the intermittent nature of rugby-play and the growing demands imposed by bout-stacking. Especially as higher-speed running ($V_{Z3\text{-}5}$) did not decrease significantly (Table 32). In turn, these kinematic results might indicate rising fatigue and pacing strategies [393, 413].

However, when accounting for player number and pitch size, multiple nuances arise, as kinematic and physiological measures show significant differences, both within formats, between consecutive bouts, and also for the same bout between different formats (Table 31). One such example for the core performance metrics is that less HIRD occurs for every added bout when formats are differentiated by player number (3, 5 ,7-a-side) and normalised for pitch size, while HIRD simultaneously increases per added bout when differentiated by pitch size (S-M-L), and normalised for player number. These data, overall, also indicate that kinematic performance measures by and large are alike for the same bouts across formats. Which is less the case for physiological measures, although no consistent differences are evident, either.

Overall, these observations support the previous results indicating the player number and pitch size have a primordial and differential influence on performance measures through their interaction with other design variables (Table 28 and Table 29). As practically, SSG formats consist of both player number and pitch size in combination, the data demonstrates the potentially confounding effect of generic "bulk-statements", i.e., directional conclusions regarding SSG structuring on SSG performance, when only accounting for either player number or pitch size. Consequently, there is a need for specificity of formats within specific contexts, like age groups.

The results for specific formats revealed that for pooled youth, significant between-bout differences mostly occurred for select formats (e.g., 3v3, L). This was the case for most physiological (HR_{AVG}, and specific V_Z and HR_Z) and kinematic performance measures (RD, V_{AVG}, HIacc/dec, AL_{3D}, impact rate, VHSRD), and especially RPE (Appendix 14: Youth SSG formats bout differences – General performance measures (imputed values R)), Appendix 15: Youth SSG formats bout differences – Speed zones (imputed values R), and Appendix 16: Youth SSG formats bout differences – Heart rate zones (imputed values R)). It appears that with more relative playing area, measure-specific increases or decreases between Bouts 1 and 2, or Bouts 1 and 3 are more prevalent. Notwithstanding, for some measures the opposite is true; e.g., 7v7-S, with the lowest relative playing area, elicited the greatest RPE in Bout 1. However, RPE seems to be an exception, with additional differences between various bouts for most other formats. In addition to the initial bout holding the highest potential to contrast following work bouts, the most suitable SSG format is performance measure-dependent. Thus, the application of bout sequencing should be outcome measure-specific, on top of format and context-specific.

Regarding RPE, the various bout-related differences observed for all youth do not corroborate with the limited bout-differences in kinematic and physiological markers. However, Borg did account for some discrepancy to be seen with HR, due to contextual fluctuations of other factors like age, environment, exercise type, and anxiety [263, 264]. Furthermore, in youth soccer players, RPE has been shown to correlate to specific external measures of training load in varying degrees [414]. Weak relationships between RPE and the kinematic measure in this study might explain why their bout differences are not in sync. Similar findings have been documented for NZ youth rugby 7s players [383]. These joint observations might furthermore indicate a lack of experience or the peer-influence of the group setting in which it was collected [266, 383]. Perceived exertion has been applied to youth populations for monitoring training but its utility is unclear at this time because of the limited evidence [265]. Nevertheless, RPE is still regarded a good indicator of global exercise intensity in youth, especially in conjunction with other measures [262, 269].

When differentiating between age groups, between-bout performance differences are evident in the data, but the quantity and directionality are a function of the specific outcome measure, as stated (Appendix 14: Youth SSG formats bout differences – General performance measures (imputed values R)). No unequivocal uniformity or trend seems apparent across all performance measures between age categories. For example, U14 players recorded 166.9 ± 19.8 m in V_{Z1} for the average bout during 5v5-M (Appendix 16: Youth SSG formats bout differences – Heart rate zones (imputed values R)). Simultaneously, this walking distance increased from Bout 1 to Bout 2 (25.7 m) and to Bout 3 (25.4 m), relative to Bout 1 (p= 0.037 and 0.040), which can be expected with the onset of fatigue and pacing strategies (Appendix 15: Youth SSG formats bout differences – Speed zones (imputed values R)) [393, 413].

Conversely, while no data was available for U15, U16 showed no between-bout differences were seen for V_{Z1} (p= 0.975 and p= 0.940). In turn, U18 showed an increase of 36.2 m from Bout 1 to Bout 2, solely (p= 0.038). The lower walking distance per bout for U16 (148.0 ± 5.6 m) as compared to U14, and the absence of increase in walking distance across bouts, could indicate that U16 were fitter than U14. However, such assumptions do not account for hidden variables like inherent motivation, and contextual factors like group dynamics and session-to-session fluctuations. In addition, U18 covered 157.2 ± 22.6 V_{Z1} meters, which rejects the assumption of a potential trend that older youth might walk less.

The context-specific bout data incorporates three between-bout comparisons per SSG format, for nine distinct formants, and fifteen general performance measures, five V_Z, and five HR_Z (Appendix 14: Youth SSG formats bout differences – General performance measures (imputed values R), Appendix 15: Youth SSG formats bout differences – Speed zones (imputed values R), and Appendix 16: Youth SSG formats bout differences – Heart rate zones (imputed values R)). From these 675 combinations per age group, the results showed 48, 36, 24, and 48 bout differences ($p \leq 0.05$) or trends ($p < 0.1$) for U14, U15, U16, and U18, respectively. Across all youth pooled, 9% of all bout contrasts demonstrated significant differences or trends to significancy, quantifying a minority of performance measures are influenced by bout-stacking.

In summary, Bout 1 can be viewed as a performance benchmark, to which standard following bouts can be modelled. As a consequence of upkeeping the higher-intensity kinematic demands, the physiological demands will rise from the second bout onwards. Bout-staking can consequently be used to create a more intermittent character, as high-intensity meters are upkept but low-intensity distance rises. Bout-staking mostly affects the perception of exertion but can be differentially effective for all age groups and across many performance measures, in a minority of SSG formats. Multiple bouts mainly seem to exacerbate the effects of extreme relative playing area (e.g., 3v3-S/L), but not exclusively. Bouts should therefore serve as an additional and flexible tool, subservient to other SSG design variables, and specific to the context.

7.4.3.2 Responses to small-sided game performance measures

Kinematic demands

An indiscriminate view on SSG^{RU} shows that youth perform between ~79 and 107 $m \cdot min^{-1}$ during work intervals. These running demands can lead to a TD of up to 1646 ± 186 m in large-format SSG (7v7, L) with V_{AVG} of ~4.2 to 5.6 $km \cdot h^{-1}$ (Appendix 10: Youth SSG general performance measures (imputed values - R)). Similar RD (~87.8 $m \cdot min^{-1}$, calculated from partials by author) were seen in RU professionals playing 6v3 (17.5x15 m) and 11v8 (35x30 m) with position-specific designs [347]. However, SSG peak (one-minute epochs) requirements have been shown to rise to 195 $m \cdot min^{-1}$ in professional RU [346]. Conversely, Vaz and colleagues reported 4 to 11 $m \cdot min^{-1}$ (graphically) in 1v1, 2v1 (30x30 m), and 7v7 (50x35, 100x70 m) SSG with professional seniors [87]. These ranges show that SSG design has important implications for running demands. The observed speeds surpass the match demands of English RU school-age youth, university players (< 72 $m \cdot min^{-1}$), and professional players active in four different competitions (~71 $m \cdot min^{-1}$) [16, 27].

Based on average match speeds (~4.1 to 5.4 km·h^{-1}) across various competition levels in NZ and internationally, NZ youth SSG average running demands rival those of local and elite-level adults [24, 28, 107, 110]. When compared to NZ youth 7s running demands (111 m·min^{-1}), only 3v3-L bouts delivered greater results for U16 (116 m·min^{-1}) and U18 (112 m·min^{-1}) [383]. Across all youth, formats that maximise individual running space are more optimal to train running capacity; 5v5 (U15) and 3v3 bouts on a large pitch will effectively maximise RD, whereas conversely, 7v7-S is universally the least appropriate.

When it comes to performance-determining high speed running efforts, the current work shows that maximising relative player area, is key. Three-a-side bouts on a large pitch, by far caters for the highest HIRD per bout (~11 m, i.e., ~2.8 m·min^{-1}), leading to ~144 m throughout the SSG. In comparison, the largest SSG formats reported by Vaz and colleagues (7v7, 50x35 m and 2v1, 30x30 m) utilising an identical threshold (≥18 km·h^{-1}) recorded approximately 20 to 30 m of HIRD for one 15-minute bout (i.e., ~1-2 m·min^{-1}) [87]. Zanin and colleagues, in turn reported ~0.6 m·min^{-1} of HSR (>61% V_{MAX} = approx. 19 km.h^{-1}; calculated from available data by author) for their SSG in a professional cohort [347]. Comparatively smaller pitches and different playing rules would likely have affected these discrepancies. Nevertheless, these cohorts (national-level seniors) would equally be expected to outperform their youth RU counterparts. However, differences in performance can manifest in technical proficiency markers, more so than physically [89]. Notwithstanding, performance differences for V_Z have been noted during SSG training in youth [306].

Our results thereby show approximately 5 m·min^{-1} of HIRD for the 7v7-Medium pitch format, which is the identical format to that of Vaz et al. (Table 34a) [87]. New Zealand RU youth therefore seems to perform at comparatively high intensities, and this observation was also made for NZ rugby 7s competition [383]. For a given speed threshold, these SSG formats can produce more relative HSRD (~1 to 11 m·min^{-1}) than U20 matches (~3 to 7 m·min^{-1}), thus preparing players for match demands [206]. Similar to the data observed for RD, U15 seemed to deviate from other age categories in terms of most suitable format, as the greatest HIRD was seen in 5v5-L rather than 3v3-L. Of note, however, is that adjacent formats (3v3-L) were statistically equal. Maximising the available running space consequently elicits similar responses in all age groups for the average running demands and this absolute HIR category.

Further to high-intensity measures, the highest sprint frequency on average was achieved in 3v3 on a medium-sized pitch (2.9 ± 1.1). Other formats showed similar results, except for 7v7-S, which had a lower sprint frequency. This observation means that maximal individual playing area is not a necessity for maximising sprint frequency, although minimising it is counter-productive (Table 34). Markedly, this frequency and all other formats' are much higher than the values previously reported for fourteen to eighteen-year-olds in training (<~0.02·min^{-1}) and matches (~0.36·min^{-1}), and for U20 forwards (~0.11·min^{-1}) and backs (~0.26·min^{-1}) [117, 206]. Methodological differences disallow for direct comparison; varying sprint definitions [145, 147, 280] and the time-frame considered can be confounding [122, 415], as well as different types of training sessions resulting in more and less movement demands compared to matches, depending [28, 119].

Considering the condensed nature of SSG and bouts, sprint frequency will logically be greater, comparatively, as most of SSG training session duration does reach peak movement intensity [346]. Conversely to our results, Kennett and colleagues reported more sprints (2.1 ± 2.4) with smaller player numbers (4v4 vs. 8v8) and larger pitches (2.5 ± 2.0) during 2x9-minute SSG. Again, a different working definition (>23 km·h^{-1}) and GPS (1 Hz) impede direct comparison [88]. As comparisons were done averaging out across pitch size and player numbers, statistical differences may have resulted due to a less granular view than when using exact formats. In professional senior GBT sessions, sprints (i.e., >21.6 km·h^{-1} for ≥1 second) have been reported to occur every 9 ± 11 minutes, similar to match play (9 ± 13 minutes) [28]. Without uniformity of operational definitions and standardisation of training data evaluation, direct comparison with our data for full SSG (1 per 27 seconds) remains unfeasible due to methodological differences, measuring equipment, and sprint definition [145, 147, 240, 242, 280]. A takeaway is that, despite age group (i.e., U14, U15) deviations from the pooled "norm" (3v3-M), various formats statistically overlap, allowing for flexibility in format selection for maximising sprinting exposure.

In contrast to sprint frequency, V_{MAX} is more sensitive to relative individual space; 3v3-L (583 m^2) showed the highest speed and was only statistically matched with adjacent formats 5v5-L (350 m^2), 3v3-M (292 m^2), and 5v5-M (175 m^2). These results suggest that a threshold-minimum individual playing area exists for targeting V_{MAX}. As expected, 3v3-L also accumulated the most HIRD (Table 34), HSRD (>20 km·h^{-1}), and VHSRD (>25 km·h^{-1}) (Appendix 10: Youth SSG general performance measures (imputed values - R)). Similar V_{PEAK} were reported, ranging from 23.3 ± 3.6 to 24.1 ± 3.6 km·h^{-1} for 4, 6, and 8-a-side in senior SSG^{RU}, or 21.3 ± 2.7 to 25.8 ± 2.7 km·h^{-1} when broken down per pitch size [88]. In agreement with our findings, larger individual playing area catered to the highest V_{PEAK}.

In 5v5 offside-touch rugby with university-age RU players, V_{MAX} was consistently around 22 km·h^{-1} for each of the 6x4-minute bouts, irrespective of augmented feedback applied [343]. These consistent top speeds demonstrate that secondary school youth RU players can achieve high speeds approximately equivalent to their older counterparts in SSG^{RU}. However, as most of SSG training session time has been document to be performed at 30 to 39% of peak movement intensity only, and match performances have revealed ranges between ~24 and 28 km·h^{-1} in U16 and U18 RU backs and forwards, these standardised SSG^{RU} might not fully meet competition speed requirements [16, 346]. The age group-related data insinuate that U14 and U15 could have a small, preferred affinity for lower relative playing area (3v3-M, 5v5-L) to trigger V_{MAX}, compared to older cohorts. Prior research in U9 indicated that optimising game constraints, such as reducing player numbers and set pieces, can for example increase ball-in-play and successful passes, leading to more fun [173]. Maximising individual space (i.e., 3v3-S) might induce less interaction and more running, which could be demotivating at younger ages that are more driven by fun [173]. There might be an optimal individual playing area that is age-group dependent, for encouraging game-like behaviour and consequently running performance. Nevertheless, statistical overlap exists between adjacent formats, allowing for flexibility in format selection.

Speed profiles in the rugby codes are often categorised in zones, mostly using absolute thresholds [93, 101, 122]. Though less common, relative thresholds have been applied to rugby and show utility towards individualised player and performance assessment [118, 146, 147, 157, 277, 278, 352]. When utilising individualised Vz in the current study, most distance per bout was consistently covered *jogging* in V_{Z2} (up to ~52 m·min^{-1} for 3v3-L). There is a tendency for proportionally more jogging and less *walking* (V_{Z1}) with higher relative playing area, and vice versa (Appendix 11: Youth SSG relative speed zones (imputed values - R)). Remarkably, all but U18 saw the most jogging in various formats other than the average format for pooled youth (3v3-L). However, here too, statistical overlap exists between formats, which means that the greatest jogging distance could be achieved within every age group with 3v3-L, among various other formats (Appendix 11: Youth SSG relative speed zones (imputed values - R)). In contrast to our results, more walking than jogging was reported in senior SSG^{RU} (V_{Z1}: 0-6.9 km·h^{-1}) and elite RL U19 (≤ 10.8 km·h^{-1}), which might indicate a more intermittent kinematic profile at the senior level [87, 200]. Of note here is that discrepancies in the working definitions of V_Z and differences in sample size impinge on meaningful comparisons between these rugby cohorts. In addition, SSG design would dictate performance outcome, as the discrepancy between walking and jogging was much larger with less relative surface area (7v7 vs 1v1 and 2v1-formats) [87], which is in accordance with our results that shows the least amount of jogging for the lowest relative surface area (63 m^2·player^{-1}) [87].

New Zealand 7s youth competition has also been characterised by more jogging [383]. In contrast to 7s youth, however, the amount of jogging and walking was more evenly divided. Furthermore, the differences observed in many formats were negligible, or overlap statistically. Although 7s have a similar game-duration (15 minutes) to these SSG, the results indicate different game dynamics, with less continuous running and notably more walking. Conversely, U19 RU match data showed that up to 81% of game time is spent standing and walking (<20% V_{MAX} match) [118]. Furthermore, adolescent players between fourteen and eighteen were found to spend up to 82% of match time below jogging speed [117]. Our data suggest that larger pitches increase distance travelled at the highest speeds. Of note, 3v3-L elicited the most V_{Z5}-meters in younger players (U14,U15), as compared to the older cohorts (U16: 7v7-L, U18: 7v7-M). However, most formats showed statistically similar values (Appendix 11: Youth SSG relative speed zones (imputed values - R)). Overall, higher relative playing area (3v3-L) seems conducive for maximising relative HSRD. In conclusion, these SSG formats can be applied flexibly to adequately prepare youths for most of their RU match distances, yet they would need modulation to meet the jogging demands of NZ youth 7s competition.

In line with the kinematic performance measures discussed, most other measures followed a similar trend; larger individual playing area causes greater demands (Appendix 10: Youth SSG general performance measures (imputed values - R)). The 3v3-L format produced the highest values for HSRD, VHSRD, and all V_Z (except V_{Z1}, demonstrated the lowest distance) (Appendix 10: Youth SSG general performance measures (imputed values - R) and Appendix 11: Youth SSG relative speed zones (imputed values - R)). However, HIacc (3v3-S) and HIdec (3v3-M and 5v5-L) were maximised with less playing area (146, 292, 350 m^2/player, respectively). The lack of space might decrease players' ability to accumulate long runs and at high speeds, but it does not seem to impinge on the initiation of actions. Despite overlapping statistical results between various formats, this data suggests moderate space with three-to-five a-side might optimise small, short burst and stop-start kinematics. Overall, a maximal bout load of 4.8 ± 1.3 AU (AL_{3D}) was observed, which is near-identical to that observed in NZ youth 7s matches (4.9 ± 1.3 AU). These loading observations consolidate the high movement demands of SSG and confirms that they can be an appropriate training stressor to prepare youth players for specific movement demands of rugby 7s [383].

In summary, the highest kinematic demands occur when relative pitch area is maximised. Across all youth age groups, 3v3 on a large pitch elicits the highest performance outputs. However, various SSG formats statistically overlap. This variety implies no one format is superior for training kinematic demands. Moreover, a range of SSG allow the flexibility for practical and logistical considerations, as well as manipulation in function of technical or tactical training. For example, running capacity could equally be trained on a large pitch with 3v3, 5v5, but not 7v7; whereas 7v7-S would minimise RD covered, which might have its utility in recovery or return-to-play, as it would lessen player load. Similarly, sprint exposure can be trained with all formats, with the exception of 7v7-S. Conversely, HIRD should exclusively be targeted with 3v3-L. Within this, it is important to acknowledge that differentiation might be necessary, as for most kinematic performance measures, subtle differences may occur between age groups for the same SSG format.

Physiological demands

Various forms of HR measurements have been consistently applied to rugby, to express the physiological load [22, 399]. With a HR_{AVG} ranging from ~79%HR_{MAX} (7v7-S/M) to 85%HR_{MAX} (3v3-L), these youth demonstrated lower cardiovascular intensity than reported for RU semi-professionals (87 – 89 %HR_{MAX}) and RL (85 – 91.5 %HR_{MAX}) professional academy youth [88, 209]. Of note, elite-level seniors were reported spending most SSG time ≥90 %HR_{MAX} for all formats, with the highest values for the smallest format (1v1 evasion vs. 2v1 and 7v7) [87]. In turn semi-professionals, spent 64-80% of SSG games above 85% HR_{MAX}, depending on field size [88]. The discrepancies with our research are likely based in the various design differences observed in these studies, among which duration and potentially influential factors such as coaching, alongside player number and pitch size [56, 88, 97, 393]. Additionally, these investigations represented high-level rugby cohorts, in contrast to our school-level players.

Five-a-side on a large pitch seems to elicit the most time in HR_{Z1} (<20%HR_{MAX}), although overlap with most other formats is evident (Appendix 12: Youth SSG relative heart rate zones (imputed values - R)). Time in "HR_{Z1}" (<75%HR_{MAX}) has been shown to have the highest predictor degree in terms of RU training performance in U16 and U18, compared to other kinematic and physiological variables such as distance in V_Z and body impacts [306]. By that notion, 7v7-S showed the most (~62% of SSG), and 3v3-S/M the least time (~38% of SSG) in $HR_{Z1\text{-}3}$ (≤80%HR_{MAX}), across all youth. Therefore, HR seems directly related to relative pitch area; less individual space lowers cardiorespiratory loading. The lower-intensity SSG agree with RU youth data reporting most GBT time is spent below 75% HR_{MAX}, albeit for full sessions, which likely lowers the intensity [306]. Generally, HR_{Z4} and thereafter HR_{Z3} showed the highest numbers across formats [88].

Youth consequently spent most of SSG time between 70-89% HR_{MAX}, with up to 7.2 ± 2.2 minutes of SSG and ~50% of bout time (3v3-M) between 80-89 % HR_{MAX}. In agreement with our research, SSG^{RU} in collegiate-level females (19.8 ± 1.6 years, 1.65 ± 0.07 m, 70.5 ± 13.1 kg) found that up to ~42% was spent at below 75% and ~38% of SSG duration was spent between 75-85% HR_{MAX}, depending on the contact rules implemented [283]. In line with their match observations (~9%), only 9 – 14% of SSG reached < 90 % HR_{MAX}. The most optimal format for peak intensity (3v3-S) showed 1.1 ± 1.2 minutes per bout of ≥90 %HR_{MAX}, or ~24% of total SSG time.

In summary, variable differences are evident between age groups for HR_Z and for the time distribution between $HR_{Z1\text{-}Z5}$ within age groups, depending on the exact format. Notwithstanding, higher relative player area causes more exposure to higher-intensity HR. Nevertheless, most of SSG time is spent at or below 80 % HR_{MAX}, with less than 25% of time at peak intensity. As for all zones in every age group, various formats are not statistically different, the optimal format for specific HR-exposure is malleable. Consequently, HR can be monitored to have an objective measure of the efficacy of the SSG applied. This measure can furthermore be coupled to subjective measures of intensity, such as RPE [264].

Perceived exertion provides a practically feasible tool which can contribute to the assessment of global exercise intensity in team sports as a measure of (psycho) physiological demands, in complement of other performance measures like HR [262, 263, 269]. RPE, which quantifies exertion on a gradual 6-20 scale [264], could help differentiate between playing levels but has been shown to not fully align with other indicators of load in (NZ) youth, therefore warranting reservation with its interpretation, especially in isolation [268, 383, 416]. Our data distinctly demonstrates that youth players experience the greatest strain with the largest (3v3-L), and the lowest strain with the smallest individual playing area (7v7-S). Across all ages, SSG were perceived as ranging from (very) light to (somewhat) hard, which aligns with research in NZ U15 rugby 7s (13 ± 1) [383]. Prior research has shown that young-adult semi-professionals perceived SSG demands to be more taxing (RPE 13-17) [88].

Parallel to our results, larger pitch size and less players were associated with higher RPE. In contrast to that, university squad RU, and elite U19 RL players reported lower values (circa. 9-10 $RPE^{6\text{-}20}$ on differential RPE scales [417, 418]) for 5v5 touch and 8v8 on/off side games [343]. However, discrepancies between kinematic measures and RPE have been reported in the football codes [383, 414]. RPE is therefore not necessarily an accurate reflection of training intensity in youth players and peer-presence can lead to appraisal-seeking behaviour [266, 414].

Contrary to recreationally trained adults who overstated RPE for non-sport-specific exercise to potentially signal high-effort work ethic, adolescent RU players could potentially be influenced to report lower exertion as a signal of fitness [266]. The design of SSG can influence RPE but as argued, level of play, professionalism, age, education, and the collection context might be determining factors [200, 266, 268, 393, 416]. Nevertheless, in our data, the highest RPE is seen for the format (3v3-L) with the highest values for most performance measures. Markedly, older players (U18/U16) demonstrated a higher range of perceived exertion, as compared to their younger counterparts, which might indicate younger players possess limited physiological proprioception or are indeed more prone to peer-influence. Practitioners should keep these discrepancies in mind when assessing youth players' training loads.

Together, these observations infer that the design of SSG (e.g., player number, pitch size, duration, rules, cohort) can lead to impactful differences in (psycho)physiological stimuli. Furthermore, professionalism of the environment seems to carry over to training intent and therefore potentially training intensity. Standardised SSG might be representative of average physiological match demands and could therefore provide some aerobic conditioning [419]. Yet, they do not inherently elicit the required cardiovascular load for VO_{2MAX} improvements reported through improved stroke volume (2-3 mins, 90-95% HR_{MAX}) and are therefore unlikely to trigger optimal physiological conditioning [44, 45, 355, 377, 378, 420]. Perceived exertion does furthermore not seem to accurately represent the training load in isolation but can be used in complement to HR as a measure of global exercise intensity, if the collection context is accounted for. Although SSG can be effective for aerobic improvement, differences between (younger) age cohorts can occur [379]. The evidence suggests that in practice, youth players need a differentiated approach in which intrinsic or extrinsic stimulation, such as fun-targeting, rule adaptation, and coaching, as well as considered monitoring might be required to optimise their conditioning.

Physical demands

Impact rate during SSG was very low across all formats (≤ 0.0 ± 0.1), which can be expected for touch rules (Appendix 10: Youth SSG general performance measures (imputed values - R)). The main design variables, player number and pitch size, seem to have little effect on impacts. The low impact rate seemingly did not carry over into a low injury incidence. With 59.8 injuries per 1000 player-hours, the injury occurrence during these SSG was within the range reported for professional RU match-play (~47 and 81·1000 pl-h^{-1}), but considerably higher than for training (~3·1000 pl-h^{-1}) [76, 138]. Of note is that various interpretations of injury have been used in a rugby context, and the current working definition was purposefully low-threshold and self-monitored [79]. To caveat, none of the recorded injuries were tackle or head-related, showed any form of external trauma, or required medical treatment. All incidents were described as discomforts (i.e., low-grade and/or pre-existing strains or sprains) .

Furthermore, our data was based on actual SSG time, rather than full training sessions. For children and adolescents up to U21 level, a review of the literature has revealed from 20 to 66 and from 28 to 130 injuries per 1000 match player-hours, depending on the cohort [74, 80]. The latter high incidence was found in a large cohort (n= 123) from the same stratum (NZ U14-U18 boys) and with a near-identical working definition of injury [421]. Although SSG are not devoid of all forms of injury, the literature is in line with our research, and standardised touch-rules SSG are at low risk for severe injuries. The SSG injury prevalence might reflect their short-duration intense nature, which makes GBT a suitable approach for the competition demands.

7.5 Conclusion

This is the first study of its kind, using randomised allocation to investigate the elemental influential factors of SSG design in RU youth for specific standardised formats. Performance in SSG^{RU} is dependent on the combination of player number, pitch size, bout accumulation, and age category. The degree to which SSG performance is influenced by these design factors is specific to the age group and the training outcome variable observed. Primarily, SSG performance is driven by player number and pitch size. Larger individual playing area increases demands for most kinematic and physiological markers of performance, with notable differences between age-cohorts. Performance differences relating to SSG structure occur for select formats and performance variables only, most prominently for RPE; bout-stacking mainly exacerbates the effects of extreme relative pitch areas and generally manifests between the first bout and subsequent bouts. These standardised SSG are a safe method to elicit high kinematic loads and general physical conditioning but they are insufficiently stimulating for optimal match conditioning in adolescents. A considered and differentiated approach is recommended when applying SSG^{RU} to youth. Practitioners can use these SSG formats flexibly, monitor outcomes, and elaborate on them to apply the desired training stimuli in their specific context, using appropriate constraints based on specific needs.

7.6 Practical applications

Practitioners should select SSG with a targeted performance outcome and a specific age category in mind. As all elemental design variables directly influence performance, and each other's effects, practitioners should primarily consider the optimal individual playing area to target the desired performance measure. In general, three-a-side touch on a large pitch (583 $m^2 \cdot player^{-1}$) is a versatile and relatively safe method to maximally target most kinematic and physiological demands of RU. High-intensity accelerations and decelerations are maximised in 3v3-S (146 $m^2 \cdot player^{-1}$) , 3v3-M (292 $m^2 \cdot player^{-1}$), and 5v5-L (350 $m^2 \cdot player^{-1}$). Seven-a-side on a small pitch (63 $m^2 \cdot player^{-1}$) might suit recovery, acceleration frequency, and technical focus to a greater extent. Practitioners can nevertheless select from a range of formats that best suit their practical context, for similar performance; a relative playing area of 350 to 583 $m^2 \cdot player^{-1}$ can accommodate various performance measures and in some cases 175 to 583 $m^2 \cdot player^{-1}$ can be used. However, more players (i.e., 7v7-L; 250 $m^2 \cdot player^{-1}$) can be counter-productive in many cases. Considered recovery intervals should be used structurally to maintain high-intensity work bouts. In addition, the strategic implementation of additional physical tasks and motivational elements should be explored, aimed at sustained high-intensity, high-quality performance.

7.7 Limitations

The nature of the data collection and processing incurred several limitations. Environmental conditions were not standardised, yet they are representative for a varied season (12-25 °C; 48-97% humidity, 1007-1026 mbar). The practical implications within these cohorts may have meant peer influence occurred and not all individuals adhered strictly to the exact protocol (i.e., start/stop, passive recovery). Measurements are therefore close approximations of the ideal and representative for "real-world" practice. Consequently, certain well-considered but arbitrary selections were made during processing of the raw data. Despite a large overall sample size, age groups are unbalanced, and due to the magnitude of outcome variables for all format variations, specific formats can be underpowered within a specific age category. Therefore, absolute values should be taken as a guideline, primarily. Further research within age categories using standardised SSG is needed to strengthen the conclusions. Of practical importance is that, although allocation was randomised, other confounding factors such as, maturation, position-specificity, psychological factors, and technical and tactical proficiency have been shown impactful but were not accounted for in this study [407, 422, 423].

KEY POINTS

- **Point 1** – Player number and pitch size are the primary design variables to influence kinematic, physiological, and physical SSG outcomes, but player age and repeated bouts matter.
- **Point 2** – Larger pitches and less players tend to maximise movement and cardiovascular demands in youth RU players.
- **Point 3** – Certain ranges of relative playing area (circa. 175 – 583 $m^2 \cdot player^{-1}$) can cater to similar kinematic, physiological, and physical outputs, allowing flexibility for the application of SSG formats to suit the practitioners' specific context.

CHAPTER 8

Match demands of youth rugby sevens

Chapter prelude

In previous chapters, the need for specific and good-quality knowledge regarding the design of SSG^{RU} was outlined and its practical application investigated. To add novel and methodologically sound knowledge to the relevant body of literature, in Chapter 7, the influence of elemental design variables on the acute demands of SSG in RU youth was experimentally established. Our investigation demonstrated that player number and pitch size are primordial in SSG design. While player age influences outcome, bout structure is also of importance. We can now state that smaller formats such as 3v3 on a small pitch are most likely to maximise kinematic, physiological, and physical performance measures. As these training games are frequently used in RU practice to prepare players for competition, Chapter 8 will now investigate the demands youth rugby sevens.

8.1 Introduction

The game of rugby sevens (7s) is played between two teams of seven players across two halves of seven minutes with a one minute-break interval, on a full-sized rugby pitch [424, 425]. Although the basic rules of play are the same as in rugby union (RU), the competition differs from other codes in its format; every team will face several opponents per day in multi-day tournament (typically 2-3 days) [424-427]. Sevens has surged in popularity since its introduction to the 2016 Olympics [91], which is exemplified by the forty teams that were hosted at the 2022 RWC 7s [428, 429]. This rising interest for 7s is also evident amongst youth; eleven nations from World Rugby's six regional associations participated in the 2018 Youth Olympics [430]. Participation in 7s has grown by 185% for secondary school-age youth between 2012 and 2020, further supporting its rise in popularity [75, 431].

Sevens competition is characterised by high RD and intermittent HIR, in support of specific defensive and offensive skills [91]. These demands have been stated to be particularly impactful, warranting specific investigation and a differentiated approach to preparation, based on game-specific demands [26, 100, 432, 433]. The evidence on 7s game characteristics is biased towards elite seniors [93, 276]. Little is known about youth 7s competition. Two studies have presented time motion data, reporting similar distances of around 1200 m for Australian and South African (SA) youth cohorts [115, 434]. Players appear to cover most of that distance walking (429 m) and sprint six times per game while reaching V_{MAX} of 31 km·h^{-1}. No HR or RPE was documented. Differences between age groups, playing level, and geographic location seem evident [115, 434]

No studies to date have investigated NZ school-age 7s population. In contrast, specific match characteristics have been studied for fifteen-a-side rugby , differentiating school age groups and senior players [16]. It is unclear how the game demands evolve during the 7s developmental pathway. Junior-level 7s should be targeted in investigations to better represent and understand the playing population, and adequately prepare these athletes [72, 93, 173, 425]. Accordingly, this study aimed at measuring, describing, and comparing the differences in movement, physiological, and perceptual demands between two secondary school-age youth cohorts competing in the national 7s competition. This data will inform practitioners about the age-related match demands of youth 7s players and can help optimise their specific development.

8.2 Methods

8.2.1 Experimental approach

A cross-sectional observational study was conducted on two youth rugby cohorts. Inclusion criteria for purposive sampling were the availability of two representative secondary school academy cohorts, competing nationally in different age categories. Perceptual, HR, and TM data were collected using wearable VX SPORT™ microsensor technology (VXWR5Lb; 10 Hz GPS, Glonass, QZSS, SBAS, Galileo & BeiDou compatible; tri-axial 100 Hz accelerometer; 18 Hz magnetometer; 18 Hz gyroscope), coupled Suunto HR monitors, and the Borg scale (6-20) [264] on two single days, during a national rugby 7s tournament. Ethics approval was obtained from the University of Waikato Ethics Committee (HREC(Health)2019#16)

8.2.2 Participants

Two male cohorts competing in their respective age-categories, under 15 (U15: n= 13; age 14.9 ± 0.3 [range14-15]; height 175.0 ± 7.0 cm; mass 75.0 ± 8.0 kg) and under 19 (U19: n= 14; age 16.9 ± 1.2 [range 15-18]; height 179.0 ± 6.3 cm; mass 88.0 ± 9.8), were involved in this study. Selection and procedures were coach-led with no researcher interference. Subjects were informed through written and verbal means about the purposes, methods, and procedures of the study prior to their participation. Written consent was obtained from the subjects and their legal guardians.

8.2.3 Data collection procedures

Subjects were initiated in the use of the microsensor units and the Borg scale during the late 2020 rugby season, within a month of the tournament [264]. The units were worn between the scapulae in purpose-built vests under the playing jerseys. Similar technology, including VX SPORT™, has been applied to team sports, the football codes in particular, and to rugby youth and 7s research [16, 101, 115, 118, 120, 216]. Review of the literature shows 10 Hz GPS to be adequate for measuring most rugby-related movement demands [245, 246, 252, 255, 256, 395-397]. A mean value of 77 ± 6% for positioning quality during match-play has been demonstrated for similar equipment [398].

Players' V_{TOP} (40 m straight-line maximal sprint) and HR_{MAX} (a rugby-specific 1200 meter shuttle run, i.e. "bronco") were established using these microsensor units following gear initiation [211, 212]. Body weight and height were collected at the start of the tournament. Microsensor units were activated before allocation to players, pre-warm-up, approximately 45 minutes before games, to secure a signal (4 – 12 satellite connections). Normal team procedures were then followed.

Data was captured for four U19 and three U15 games in summer conditions (18-24°c; 60-86% humidity, uncovered dry natural grass pitches). Games were approximately 1.5 – 2.5 hours apart. Playing halves lasted seven minutes and half-time breaks ran up to five minutes. Rolling substitution was applied. RPE was collected verbally from individual players within fifteen to thirty minutes post-game, during group debriefing. No RPE was collected for U19 due to inconsistent player availability.

8.2.4 Data handling procedures

Microsensor data was downloaded using the manufacture's software (VX View version 5.4.3.53). Individual players' kinematic and physiological data was visually assessed and manually trimmed to solely include actual playing time. Fourteen corrupted HR and four kinematic data files (technical malfunction or misuse) were identified via numerical and graphical assessment, and subsequently removed. Individual data files were coded for playing minutes by rounding up or down to the nearest full minute. Considering seven-minute playing bouts were limited (30/53 U15; 46/71 U19) due to coaching, continues substitutions, and long half time, twenty-two bouts shorter than a quarter of a game (< four minutes) were excluded from further analysis to retain higher statistical power, in the awareness this might overestimate movement variables [115, 274].

Up to fifty-four (U19) and forty-four (U15) data files were included for analysis of respective outcome measures across all games. Variables and metrics commonly used in rugby were selected as available, and labels adopted from the software package; specific variables and categories were consequently reported as relative to individual players' maximal values [93, 122, 275, 276]. V_{TOP} and HR_{MAX} were based on the highest absolute recordings during baseline testing or matches, whereas V_{MAX} refers to the highest speed performed during games. Where players' HR_{MAX} was unavailable, a theoretical age-specific HR_{MAX} was calculated using (208 – 0.7 x age) [234]. HIR category labels were adopted from the available software options, and set to converge with benchmarks put forward in systematic research [93]; HIRD (>18 $km{\cdot}h^{-1}$), HSRD (>20 $km{\cdot}h^{-1}$), and very high-speed running distance VHSRD (>25 $km{\cdot}h^{-1}$).

High-intensity acceleration (HIacc) and deceleration (HIdec) thresholds were kept to the manufacturers setting of 3 m·s^{-2}, based on prior 7s research [115]. Relative speed zones (V_Z) provide a more appropriate perspective on youth and lower-level play [277]. The V_Z were defined as <20% (z1), 20-50% (z2), 51-80% (z3), 81-95% (z4), >95% (z5) V_{TOP} [24, 118, 278]. Relative HR_Z were adapted from Higham et al. (2016), based on Edwards (1993) to be ≤59% (z1), 60–69% (z2), 70–79% (z3), 80–89% (z4), and ≥90% (z5) HR_{MAX} [275, 279]. To contextualise impact rate in the discussion, regarding its specific nature [435], we rapport "body impacts" as the range observed for all actual playing bouts recorded. Further explanations regarding metrics-terminology and definition are available in the VX Sport metrics glossary [280].

8.2.5 Statistical analysis

Established data points were exported to an Excel worksheet (Excel 2016, Microsoft Office) and statistically analysed using the additional "data analysis toolpak". Anthropometric data and baseline measurements were analysed by independent sample T-tests. All absolute data was normalised to per minute, i.e., relative, and per full game total values, i.e., 14 minutes, for meaningful comparison. Descriptive statistics are reported as mean ± SD. Differences within and between groups were calculated using independent sample T-test and single factor ANOVA. Heterogeneity was checked through F-test. Statistical significance was set at $p \leq 0.05$. For multiple pairwise comparisons Bonferroni correction was applied [281]. Standardised mean changes were also calculated as Cohen's d_s ES, using the pooled SD, to indicate trivial (<0.2), small (0.2 – 0.59), moderate (0.6 – 1.19), large (1.2 – 1.99), very large (2.0 –3.99), and extremely large (≥4.0) magnitudes of difference [284, 285].

8.3 Results

Both cohorts showed significant differences in age ($p< 0.0001$; $d_s= 2.2$) and body mass ($p< 0.001$; $d_s= 1.5$). A trend to significantly higher stature was also measured ($p= 0.7$; $d_s= 0.6$). No significant differences were found for baseline V_{MAX} ($p= 0.42$; $d_s= 0.1$) and HR_{MAX} ($p= 0.19$; $d_s= 0.3$). A pooled set of 98 data files (U15 + U19), i.e., playing bouts (playing minutes per player), were identified with an average duration of 5.8 ± 1.8 minutes. Twenty bouts did not meet inclusion criteria for duration and were excluded from further analysis. Mean game movement demands for cohorts are reported in Table 35. U15 showed significantly greater TD, RD, $V_{AVG,}$ and higher sprint frequency, than U19, with a moderate ES. Small to trivial ES were found between age groups for V_Z (Table 36) and HR_Z (Table 37), with significantly greater distance in V_{Z2} and V_{Z3} for U15. Thirty-five post-game RPE values were collected across three U15 games for players' respective playing bouts. Body impacts were 0 – 4 for U15 and 0 – 7 for U19. Most distance was covered at low relative speed (<50% V_{TOP}) in both cohorts (Table 36) The majority of the game time was performed at very high heart rate, relative to the players' maxima (Table 37). U19 placed 9/31 and U15 placed 5/29 in the final tournament ranking.

Table 35 Age group sevens mean game movement demands

	Pooled	U15		U19			
Variable	Mean ± SD	Mean ± SD	Range	Mean ± SD	Range	p	ES
Total distance (TD) (m)	1559.0 ± 166.2	1619.5 ±186.6	[1078.0 – 1960.0]	1509.7 ± 147.7	[1232.0 – 1792.0]	<0.01[#]	Moderate
Relative distance (RD) ($m·min^{-1}$)	111.4 ± 11.9	115.7 ± 13.3	[77.0 – 140.0]	107.8 ± 10.5	[88.0 – 128.0]	<0.01[#]	Moderate
Average speed (V_{AVG}) ($km·h^{-1}$)	6.7 ± 0.7	6.9 ± 0.8	[4.6 – 8.4]	6.5 ± 0.6	[5.3 – 7.7]	<0.01[#]	Moderate
Maximal speed (V_{MAX}) ($km·h^{-1}$)	27.6 ± 2.9	27.6 ± 2.7	[22.3 – 33.4]	27.7 ± 3.1	[19.2 – 33.7]	0.92	Trivial
HIRD (m)	251.7 ± 102.0	265.1 ± 99.7	[74.0 – 448.0]	240.8 ± 103.8	[20.0 – 514.5]	0.24	Small
HSRD (m)	165.7 ± 87.5	171.2 ± 84.0	[20.0 – 380.8]	161.3 ± 90.3	[0.0 – 430.5]	0.58	Trivial
VHSRD (m)	45.9 ± 51.3	48.5 ± 56.1	[0.0 – 204.0]	43.8 ± 47.0	[0.0 – 182.0]	0.66	Trivial
Sprints rate (per full game)	41.6 ± 7.6	44.3 ± 9.2	[28.0 – 63.0]	39.4 ± 6.1	[24.0 – 54.0]	<0.01[#]	Moderate
HIacc (per full game)	41.8 ± 11.6	42.3 ± 12.5	[12.0 – 62.0]	41.3 ± 10.7	[16.8 – 70.0]	0.68	Trivial
HIdec (per full game)	16.3 ± 6.4	17.3 ± 6.4	[4.0 – 31.5]	15.5 ± 6.5	[2.0 – 31.5]	0.17	Small
Average heart rate (%HR_{MAX})	90.0 ± 3.9	90 ± 3	[79 - 95]	89 ± 4	[70 – 95]	0.73	Trivial
ActivityLoad 3D rate (AL_{3D}) (AU)	4.9 ± 1.0	5.2 ± 1.4	[0.0 – 7.1]	4.7 ± 0.6	[3.6 – 6.2]	0.06	Small
Impact rate (IR) ($impacts·min^{-1}$)	0.07 ± 0.26	0.05 ± 0.21	[0.00 – 1.00]	0.09 ± 0.29	[0.00 – 1.00]	0.36	Trivial
RPE (6 – 20)	-	13 ± 1	[7 – 15]	-	-	-	-

[#]Significant difference between groups

Table 36 Match distances covered in relative speed zones for sevens age groups (m)

	U15	U19		
V_Z (m)	Mean ± SD	Mean ± SD	*p*	ES
z1 (<20%V_{TOP})	402.1 ± 82.4$^{\forall}$	432.0 ± 77.5	0.07	Small
z2 (20-50% V_{TOP})	824.4 ± 165.8	750.5 ± 125.9	0.01$^{\#\#}$	Small
z3 (51-80% V_{TOP})	360.4 ± 122.6$^{\forall}$	315.3 ± 97.2	0.04$^{\#}$	Small
z4 (81-95% V_{TOP})	48.0 ± 47.0	41.1 ± 42.6	0.45	Trivial
z5 (>95% V_{TOP})	3.5 ± 7.4	5.7 ± 11.5	0.26	Small

$^{\#}$Significant difference between groups; $^{\#\#}$Additional significance for Bonferroni-correction; $^{\forall}$ No significant between zone difference within cohort for Bonferrroni-correction.

Table 37 Time spent in relative heart rate zones for sevens age groups (% full game time)

	U15	U19		
HR_Z (%full game)	Mean ± SD	Mean ± SD	*p*	ES
z1 (≤59%HR_{MAX})	0.3 ± 1.26	0.2 ± 1.0	0.93	Trivial
z2 (60–69% HR_{MAX})	1.4 ± 3.0	2.3 ± 6.8	0.44	Trivial
z3 (70–79% HR_{MAX})	8.0 ± 12.2	7.4 ± 11.1	0.70	Trivial
z4 (80–89% HR_{MAX})	32.3 ± 19.5	33.3 ± 22.1	0.81	Trivial
z5 (≥90% HR_{MAX})	57.9 ± 24.1	56.8 ± 26.4	0.42	Trivial

8.4 Discussion

To the best of our knowledge, this is the first study characterising the 7s match demands in the NZ educational pathway. The results outlined differences between U15 and U19 for TD, RD, V_{AVG}, sprint rate, AL_{3D}, and distances covered in V_Z, whereas times spent in HR_Z was similar for age groups. NZ school 7s competition was found to have high HIR and cardiovascular demands compared to average 7s and representative RU groups, while not being perceived concurrently.

As a first marker of high match demands, TD was similar to that of international-level male 7s players (1574.4 ± 267.4 m) [239]. In comparison, two studies found lower TD of 1213 m by junior elites in an Australian national tournament and 1133 m to1185 m in a SA provincial tournament [115, 434]. Of note here is that youth 7s covered 39% of the TD for representative RU matches, in 18% of game the game time [16].U15 covered significantly more TD per game than U19 (~110 m) and demonstrated a larger inter and intra-player variability. Previous football-related research has demonstrated relationships between league placement and match distance covered, alongside VO_{2MAX} [436-439]. As the U15 arguably were the more successful squad considering their higher relative tournament placement, their superior running values might have contributed. Other factors, such as squad and opponents' playing level, as well as players' technical proficiency will also affect tournament outcome [91, 291, 386]. Additionally, the observed differences may be exacerbated by the current competition context and study methodology, and methodological discrepancies between studies [93].

When accounting for match duration, the average RD was greater for these NZ cohorts (111 vs 109 $m \cdot min^{-1}$) than for a broader population sample, including senior and elite-level players [93]. Previous values found for male junior 7s players were also lower (103 ± 8 $m \cdot min^{-1}$) [115]. These differences are larger with RU, where U16 and senior professionals have been reported to cover just over half this youth 7s cohort's RD [16, 28]. In line with their TD, U15 had higher running demands than U19, which in turn approximated the average RD reported in the literature, which is skewed towards senior cohorts [93]. Prior research in rugby has documented differences in movement demands between school-age cohorts, while older youth demonstrate similar movement patterns to the senior game [16]. Most investigations conducted on male international 7s players indicate RD between ~79 and 112 $m \cdot min^{-1}$ for full matches, with values of 121 $m \cdot min^{-1}$ in select cases [93, 274]. This variability demonstrates a strong context dependency in 7s rugby.

In conjunction to the distance covered, the speeds at which movements are executed can be considered from various perspective towards the impact on match demands in these 7s youth. In line with general findings in the rugby codes, both age groups covered most of their distances at low speeds relative to their V_{TOP} [22, 26, 104, 219, 220, 274, 275]. On average, 7s youth movement speed concurs with the 7s literature (6.5 $km \cdot h^{-1}$) [93]. This V_{AVG} surpasses that of national and international youth and senior RU performances, as well as some, but not all elite-level 7s matches [16, 24, 93, 107]. On the other hand, these youth 7s' V_{MAX} approximated that of world class 7s players' average V_{MAX} during international matches (27.9 $km \cdot h^{-1}$) [275].

Between both cohorts, it is evident that U15 ran faster on average than U19 (~0.4 $km \cdot h^{-1}$). Concurrently, the younger cohort exhibited more variability in V_{AVG}, which could indicate less uniformity in running performance between players at younger ages. V_{MAX} was however similar for both 7s age groups and is comparable to that measured in U16 and U18 RU backs (27.0 – 28.4 $km \cdot h^{-1}$) [16]. The similarities between age cohorts could indicate that V_{MAX} remains relatively unaffected in the academy pathway, despite more training years. Similar to our investigation, Clarke et al. (2016) reported small differences in V_{MAX} for male 7s athletes, across playing levels [115].

In relation to movement speed, research on English academy RU players has associated higher body mass in older youth cohorts with lower sprinting velocity [440]. In our investigation, a higher body weight for U19 nevertheless resulted in equal V_{MAX} between both age groups. There might potentially be larger differences between the rugby codes. Considering the importance of sprinting and HIR for 7s performance, anthropometrics are an important factor to consider in the development of youth 7s players [167, 386]. As the distances travelled in medium-to-high speed bands can increase during consecutive tournament matches, but frequencies of higher-speed running can decrease, it is important to prepare for those competition demands [441]. Research has shown a relatively uniform performance standard in 7s players and between positions, which might facilitate group conditioning [92, 220]. A larger study sample could clarify whether the school rugby academy selection process does indeed cater for small between-athlete variability in performance characteristics, in NZ youth.

To further quantify the competition demands of 7s rugby, absolute speed thresholds are commonly applied, often based on empirical best practice, citation, or arbitrary standards [93]. Movement categories have been found helpful in predicting success in 7s youth competition [434]. Research suggests that higher amounts of HIR, VHSR, alongside sprinting can be indicative of performance outcome and playing level [386, 442].

Contradicting evidence shows the relationship between kinematics and competition outcome is complex, and technical and tactical factors play a substantial role [239, 443]. Approximately 16% of our cohort's TD was covered at or above ~18 km·h^{-1}, commonly referred to as HIR [93, 122, 146]. Despite the teams' tournament rankings in the current study, both groups performed similarly for HIRD, HSRD, and VHSRD. Only six studies on senior male 7s players found similar or greater HIRD (circa. >18 km·h^{-1}) and HSRD (circa. >20 km·h^{-1}) [220, 274, 386, 444-446]. VHSRD in this study was at par with that of top eight SA elite junior squads (45.9 ± 45.1 m >24.1 km·h^{-1}) [434], and only accounted for 3% of TD. In complement to absolute speed benchmarks, relative Vz have been shown to differentiate between players' profiles, especially regarding HSR [146, 277, 352, 447, 448].

Further to that, Van den Berg and colleagues showed that walking distance may also help to discriminate between successful and less successful youth 7s teams [434]. Youth 7s players in this investigation covered more than 70% of TD at submaximal, yet considerable speeds relative to players' V_{TOP}. Less walking (z1) (~27% TD) than j*ogging* (z2) (~50% TD) was recorded. RU youth on the contrary, were found to spend around three-quarters of game time stationary or walking, while jogging small amounts [117, 118]. Furthermore, SA U18 provincial 7s teams have demonstrated more "walking" (35% TD), but less "jogging" (35% TD) and "running" (14% TD) than these NZ players [434].

Between these NZ youth teams, U15 performed significantly more *jogging* (~51% vs. ~50% TD) and *striding* or *cruising* (z3) (~22% vs. ~21% TD) as commonly labelled, than U19 [22, 104]. Evidently, the surplus in TD favouring U15 is accounted for by a more dynamic movement profile. The U19 showed a trend towards more *walking* (z1) (~29% TD) versus U15 (~25% TD), which might help explain differences in overall performance, as less successful youth 7s teams have been found to walk more [449]. The discrepancies in low and high speeds between 7s cohorts, and with RU youths might indicate youth 7s competition to be less intermittent but more continuously intensive, especially at younger ages.

The frequency of short-duration high-intensity efforts is an important factor to consider for establishing match demands, as impactful movement speeds might not reach absolute or relative thresholds. The observed absolute sprint count in our investigation (19.4 ± 4.8) matches that of Premier Grade club RU players (12.6 ± 6.9 – 28.0 ± 8.6), despite considerably shorter playing bouts [171]. Moreover, the relative sprint count is eightfold that of adolescent RU match play (2.97 vs. 0.36 min^{-1}) [117]. This higher sprint rate and consistent trivial and small differences seen in absolute HIR categories, HIacc, HIdec favour the more successful team (U15).

Indeed, Van den Berg et al. (2013) observed that more successful teams sprinted more distance, duration, and frequency [434]. HIacc but not HIdec count was higher than reported for international 7s matches (7.5 ± 2.0 vs. 3.9 ± 1.0 and 2.8 ± 1.1 vs. 3.1 ± 0.8 min^{-1}) [275]. These values could indicate a difference in game dynamics between the youth and senior level. These loads should be taken into consideration, as maximal acceleration values can reach 3.6 ± 0.4 $m \cdot s^{-2}$ in youth [115]. The aforementioned HIR performances suggest high anaerobic taxation. If such discrepancy between U15 and U19 would persist, this could indicate a comparatively suboptimal development of U19 glycolytic work capacity [167].

The cardiovascular response during 7s games can divert from the kinematics due the game's intermittent nature, slow HR kinetics, and various extraneous influences [215, 239]. Very high cardiovascular taxation was nevertheless observed throughout these youth games (90 ± 4 %HR_{MAX}). In comparison, world class players have been reported to reach 86 ± 5 %HR_{MAX}, concurrent with significant blood metabolite accumulation [275]. Similar intensities were seen in various rugby small-sided games (SSGs), including two 7 v 7 formats; most of the game was spent at or above 85% HR_{MAX}. Reported HR_{AVG} were between 87 – 89% of HR_{MAX} [87, 88]. Since substitute players tend to have higher movement variables, this could have influenced HR_{AVG} [274]. No differences were found between cohorts for cardiovascular load. This could indicate that HR might not accurately discriminate for match load in youth 7s age groups. More youth-specific 7s research is needed to clarify the effect of age has on HR measures when compared to senior players.

In complement to kinematic load and HR monitoring, the Borg-scale holds utility as a holistic indicator of psychophysical strain in simple and general circumstances [264]. For these youth 7s matches, Cardiovascular taxation did not seem to corroborate with U15's "somewhat hard" perceived exertion (cf. 130 $beats \cdot min^{-1}$; cycle ergometer; 30-50 years) [264]. A similar observation for 7s was made by Blair et al. (2017) [239]. Of note is that forms of RPE and HR monitoring have been used to monitor global internal exercise loads in youth soccer matches [268, 269]. Yet, RPE's context-dependency and its relationship to HR in isolation is not consistently sufficiently strong; other factors such as lactate strengthen its validity [262-264, 267, 268].

When compared to elite-level 7s players (sRPE[10] 7), U15 reported their match efforts to be lower [239]. For the elite environment, it was argued that a tournament setting is suboptimal to collect RPE measurements, as multiple external factors might be of influence. Considering the impact of such influences on professionals, it is likely they will have an effect on youth players. Further to that, it is plausible that younger players' perceptions are insufficiently developed to adequately gage physical load and additional familiarisation was needed.

In this study, shorter playing bouts due to rolling substitutions could also have affected players' RPE. No other youth 7s competition RPE data is available for further comparison.

Collision frequency and intensity during matches and training have been documented in the literature [450]. Yet, limited attention has been given to youth 7s cohorts. The evidence shows that 7s have a distinct profile to RU; 7s players perform more tackles and ball carries into contact. Our results show similar impact rates with large variances between players for both cohorts (U15 vs U19), yet lower than previously reported for junior, senior, and elite 7s players (>10g) [115]. The upper range of recorded "body impacts" overlaps with average values reported for male 7s (~$1 \cdot min^{-1}$) [115]. This discrepancy could be due to a difference in evasion skills; however, differences in definitions, units, and thresholds used across studies lead to disparities observed in the literature and make comparisons difficult [122, 396, 450]. Since contacts are an inherent part of the game, accurate impact measures could be a meaningful and useful addition to help register and differentiate in training and match load [129, 396].

By extension of impact measurements, the athlete load (AL_{3D}) summarises U15's trend to undergo higher match loads than to U19, which can be explained by this younger cohort's higher values on several kinematic parameters. Proxy-measures of loading have been reported for RU youth (PlayerLoad rate 5.6 ± 0.9 - 7.3 ± 0.7) [16], these indicators of external load can be a reference point, within athletes or cohorts using the same devices. A critical perspective should be held when interpreting measures of impact and load [205]. In this regard, the limited impacts observed in our research are relative and a product of the innovative VX SPORT™ approach, as an alternative to "G" measures, integrating threshold and discriminatory mechanisms to produce a meaningful impact perspective [435].

In summary, the data demonstrate that NZ secondary school-age 7s players can run further and at a greater rate with possibly lower impacts in a national 7s competition than senior 7s on the state, provincial, and international level. Furthermore, youth 7s matches require a much higher work rate than equivalent RU games. Youth 7s players seem to mainly operate at submaximal relative speeds. Yet, greater match distance is covered at higher speeds with very high sprint rate, in comparison to their 15-a-side RU counterparts. This continuous high-intensity match profile results in sustained near maximal HR. These demands impose high physiological and kinematic loads on 7s players, especially in the younger age group. The study results consequently underpin youth specificity in addition to 7s specificity, as previous established by Ross et al. (2014) [100].

8.5 Conclusion

This novel study describes and differentiates the match demands of NZ male secondary school-cohorts competing in national rugby 7s. A comparison is provided between two youth teams, and with their senior and international 7s peers, as well as RU peers. NZ youth 7s players seem to experience very high physiological and kinematic match loads, characterised by very high HR_{AVG} and continuous running demands, performed at moderate to high speeds. Younger players appear to cover more distance, at a higher pace, and perform more sprints in comparison to their older counterparts. As a consequence, younger players may experience higher overall physiological, kinematic, and perceived workloads. As these match demands are the result of complex interactions of environmental, situational, tactical, and variable factors, consideration of the implications of the competition context, age group-related differences, as well as the methods used for training and monitoring is of the essence.

8.6 Practical applications

Practitioners should be aware of the continuous high-intensity nature of youth 7s games, as players operate at or above jogging speeds with sustained near-maximal HR. Player preparation should be 7s-specific to reflect these competitive demands by improving both the aerobic and anaerobic capacity. As performance efficiency in training should match the demands of competition and should be optimised through repeated HIR and sprinting, HIacc, HIdec, and minimising walking, resulting in high RD for lower internal loads [167, 274, 275, 432]. Such training stimuli can improve physiological fitness markers critical to high-intensity rugby performance, such as velocity reached at VO_{2MAX}, at the onset of blood lactate, and lactate threshold [137, 139]. SSG may also offer a dynamic training method that matches competition demands; in which high work rates in and high internal (cardiovascular) load can be achieved, while simultaneously improving technical skills and tactical awareness [275, 276, 433]. Differentiation between age groups is recommended and indication of perceived exertion should be trained within youths. Measures of internal and external load can be discrepant; coaches can use a combination of RPE, HR, and kinematic measures to monitor competition to inform training practice.

8.7 Limitations

This study incorporated data from two school-age cohorts of modest sample size, in seven matches during a national-level NZ-based 7s tournament. The interpretation of results must be done with reservation considering the differences in monitoring equipment as well as kinematic categories, and the disparity in contexts, methodologies, and data reporting in the literature [93]. Further youth-related 7s investigations are warranted to extrapolate and scale these initiatory conclusions.

KEY POINTS

- **Point 1** – Youth rugby sevens players can demonstrate higher running demands than seniors; younger rugby sevens youth players (U15) appear to experience greater movement demands than older rugby sevens youth players (U19).
- **Point 2** – Rugby sevens youth match demands have an explicit high-intensity profile that is greater than established for youth 15-a-side rugby union games.
- **Point 3** – Practitioners can progress youth players through developing sevens-specific high-intensity performance, using age-appropriate methods for maximising the capacity to perform repeated and sustained high-intensity efforts.

CHAPTER 9

Fifteen-a-side match demands of U19 rugby union players

Chapter prelude

As we have investigated the importance and the characteristics of rugby and the relevance of SSG in the literature and in practice, this thesis has now documented the demands of SSG formats and a LSG such as rugby 7s in youth players. In Chapter 8, these 7s match demands were established to be very high in terms of kinematic and physiological load. Furthermore, differences were noted between older (U19) and younger (U15) age cohorts. Considering the thesis aim of applying SSG and LSG to RU, it is now of the essence in Chapter 9, to investigate and establish the match demands for youth RU competition.

9.1 Introduction

Rugby union (RU) is a fifteen-a-side intermittent high-intensity field-based contact sport characterised by dynamic and set plays like sprints, jumps, passes, rucks, mauls, tackles, and tries [1, 451]. The game requires physical, technical, and tactical components to be considered [22]. The match-play characteristics of RU competition have been extensively investigated [26] regarding total [25] and part-time demands [106, 112], positional and game differences [81, 109, 112, 452], substitution effects [273], competition level [27, 453], and discrepancies with and prescriptions for training [23, 28, 111, 171]. By and large these studies have prioritised senior professional and elite-level players. Increasingly so, wearable microsensor technology has facilitated mapping out physiological and kinematic demands [122, 240, 282].

As the largest of the rugby codes, RU is played worldwide by men, woman, and children, locally, nationally, and internationally [70]. The sport reaches a global audience and is set for further growth by its governing body World Rugby [10, 454]. World Rugby's latest annual review (2021) reported 84.279 "active" New Zealand (NZ) players (registered teams) and 135.833 "total participants" engaged in any form of non-structural RU. With 5.223.100 estimated residents (June 2023), this participation rate is approximately 4.2% of the NZ population [70, 455]. New Zealand RU competition is played on various levels [456]. Between-match and competition differences in player characteristics and demands have been documented in NZ-based and international competitions [81, 98, 110]. Below the senior level, within the New Zealand educational pathway, RU is also a popular sport that has been reported in the top-three for meaningful engagement in the school setting [75]. Despite comprehensive knowledge regarding senior and elite-level RU performance, investigations on adolescent game-play are scarce and NZ school-level competition data seems limited [383].

As anthropometric, physical, and skill-related characteristic have been demonstrated to differ between age cohorts and between playing position, and associations exist with playing level and performance metrics in RU and rugby league (RL), cohort-specific match analyses are necessary to inform training and playing practice [98, 102, 440, 457-459]. As such, studies have described the movement demands of specific university-age RU cohorts. Ball et al. showed that backs had greater weekly movement demands than forwards, including total distance (TD), relative distance (RD), high-intensity running distance (HIRD), sprinting distance, high-intensity acceleration (HIacc) and decelerations (HIdec), sprints, collisions, and high-intensity efforts. In turn, Ungureanu and colleagues indicated that running demands in U20 elite players are affected differently by technical and tactical performance for forwards and backs [460].

Discrepancies between age groups were found for positions by Cunningham et al., in that elite-level U20 forwards covered more relative high-speed running (HSR) and were involved in more sprints, as well as moderate and high accelerations than their senior counterparts, despite a lesser high-metabolic load distance (HML) and lower severe intensity deceleration amounts . Other differences included, higher relative distance (RD) , greater HML distance, HML efforts, and more heavy decelerations for senior backs than for U20 backs. In turn, U20s backs sprinted more often and demonstrated more relative HSR [206].

For secondary school-age players, comparison between international-level U18 and senior RL players showed seniors to perform more offensive carries, and defensive tackles, but no differences were found in locomotor measures. Nevertheless, total distance (TD), individual high-intensity distance, HIacc, and HIdec were greater for back versus forwards, in both age groups [113]. Within elite-level adolescent RL players, U15 and U17 did not show differences in kinematic, heart rate (HR), perceptual, nor technical actions, between selected versus unselected cohorts [207]. In contrast, U16 selected players covered more TD, HIRD, and distance in relative speed zones (Vz) 1, 3, and 4, than unselected players. Summated HR (AU) and session rating of perceived exertion (RPE) were also higher in selected U16 [207].

For RU competition, limited motion analysis has been conducted internationally for youth cohorts. Australian national-level U16 match analysis revealed a TD of 5.8 km at an average speed (V_{AVG}) of 4.3 km·h^{-1} [119]. Forty-three percent of total time was spent stationary, 35% walking, and 14% jogging, which was similar to training. However, with 6% striding, 2% sprinting, and 1% maximal sprinting, significantly more time was spent in high-intensity zones as compared to training. South-African provincial-level U19 ran 4.5 km and spent approximately 72% of game time standing or walking. In this cohort, positional differences were observed in jogging and sprinting time, and impact frequency and severity [118]. In turn, French U18 were shown to cover ~7% more RD than U20 , ~23% more high-speed running (HSRD), ~8% more very-HSRD (VHSRD), ~23% more accelerations, and ~1% more contacts, with varying degrees of practical meaningfulness. Position-specific differences were also seen across age groups [461]. These cohorts were competed at international level, however. Comparatively, elite-level English U18 forwards and backs ran approximately 4.7 and 5.2 km, whilst positional differences in tackles and collisions were very likely. Roe and colleagues furthermore showed that different forms of player load measurement (Player Load™ vs Player Load™ 2D vs Player Load™ Slow) differentially quantify, and therefore inform the total match demands for different positions [121].

In contrast to these high-level youth players, within the English educational pathway, Read et al. has demonstrated that within and between RU cohort discrepancies in match demands exist [16]. Age and position-related differences can be found simultaneously for specific kinematic measures; forwards are likely to cover more TD than backs in U16, whereas the opposite was seen in university-age players. In U18, RD was likely lower for forwards than backs. When compared between age groups, U16 very likely sprinted less and jogged more than U18, and very likely experienced higher relative Player Load. Likely to most likely differences between cohorts are evident in metrics, such as V_Z, while for other match outcomes differences are unclear [16]. However, an equivalent perspective that quantifies NZ youth RU competition is lacking.

As age, playing level and status, competition, and position influence match-play characteristics, cohort-specific match demands are needed to inform and differentiate training practice [72, 207, 459]. A purpose-developed and adequately delivered training program can thereby improve performance measures and prepare players for the physical match demands in adolescent RU players [462]. The research is however biased towards seniors and elite-level play and is limited in adolescent RU play. Considering the impact of RU in NZ and the educational pathway, and the lacking knowledge of school-level match demands, this study aimed to analyse and describe the kinematic, physiological, and physical characteristics of U19 NZ secondary school RU players.

9.2 Methods

9.2.1 Experimental approach

A cross-sectional observational study was conducted on a NZ secondary school rugby team competing in the national 2021 competition. Perceptual, (HR), and kinematic data were collected using wearable VX SPORT™ microsensor technology (VXWR5Lb; 10 Hz GPS, Glonass, QZSS, SBAS, Galileo & BeiDou compatible; tri-axial 100 Hz accelerometer; 18 Hz magnetometer; 18 Hz gyroscope), coupled Suunto HR monitors, and the Borg scale (6-20) [264]. Institutional ethical approval was obtained (HREC(Health)2019#16).

9.2.2 Participants

One secondary school first XV (U19) RU squad was involved through availability sampling. Twelve forwards and nine backs were monitored (n= 21; age 16.3 ± 1.1 [range 15-18]; height 181.3 ± 6.2 cm; mass 85.8 ± 8.9 kg). Selection and procedures were coach-led with no researcher interference. Subjects were informed through written and verbal means about the purposes, methods, and procedures of the study prior to their participation. Written consent was obtained from the subjects and their legal guardians, where needed.

9.2.3 Data collection procedures

Data was collected for two random eighty-minute games in April and May 2021, in mostly dry conditions with showers on uncovered natural grass pitches (18 – 21 °C, 75-95% humidity, 1017 mbar, and 16-19 °C; 60-86% humidity, 1028 mbar). Ratings of perceived exertion were collected 15-30 minutes post-match in written format. Normal team procedures were followed with minimal researcher interference.

Subjects were initiated in the use of the microsensor units and the Borg scale prior to competition [264]. The units were worn between the scapulae in purpose-built vests under the playing jerseys. Similar technology, including VX SPORT™, has been applied to team sports, football, and rugby [16, 101, 115, 118, 120, 216]. Review of the literature shows 10 Hz GPS to be adequate for measuring most rugby-related movement demands [245, 246, 252, 255, 256, 395-397]. A mean value of 77 ± 6% for positioning quality during match-play has been demonstrated for similar equipment [398].

Players' top speed (V_{TOP}) (40 m straight-line maximal sprint) and maximal heart rate (HR_{MAX}) (a rugby-specific 1200 meter shuttle run, i.e. "Bronco") were established using these microsensor units following gear initiation [211, 212]. Body weight and height were collected at the start of the season. Microsensor units were activated before allocation to players, during warm-up, approximately 30 minutes before games, to secure a signal (4 – 12 satellite connections).

9.2.4 Data handling procedures

Kinematic and physiological microsensor data were downloaded onto the manufacture's software (VX View version 5.4.3.53), graphically and numerically assessed, and manually trimmed to include actual playing time. Individual data files were coded for playing halves and playing minutes by rounding up or down to the nearest full minute. Eighty-three data cases were exported to an Excel spreadsheet (Excel 2016, Microsoft Office), individually coded for missing kinematic or HR measures, and normalised to one and forty-minute values. Full match data was obtained using complementary halves, to total 118 observations. After synchronising partial data files, 106 cases were imported into SPSS software (IBM SPSS Statistics Version 29). Based on prior research, cases with less than the average team playing time were excluded from further analysis to mitigate skewing mean match demands [16, 24, 274]

Variables and metrics commonly used in rugby were selected as available, and labels adopted from the software package; specific variables and categories were consequently reported as relative to individual players' maximal values [93, 122, 275, 276]. V_{TOP} and HR_{MAX} were based on the highest absolute recordings during baseline testing or matches, whereas maximal speed (V_{MAX}) refers to the highest speed performed during games. Where players' HR_{MAX} was unavailable, a theoretical age-specific HR_{MAX} was calculated using (208 – 0.7 x age) [234]. High-intensity running categories were based on the software, and set to converge with benchmarks put forward in systematic research [93, 101]; HIRD (≥18 $km \cdot h^{-1}$), HSRD (≥20 $km \cdot h^{-1}$), and VHSRD (≥25 $km \cdot h^{-1}$). High-intensity acceleration and deceleration (HIdec) thresholds were kept to the manufacturers setting of ≥3 $m \cdot s^{-2}$, based on prior 7s research [115]. Speed zones provide a more appropriate perspective on youth and lower-level play [277]. The V_Z were defined as <20% (z1), 20-50% (z2), 51-80% (z3), 81-95% (z4), 96-100% (z5) V_{TOP} [24, 118, 278]. Relative HR zones (HR_Z) were adapted from Higham et al. (2016), based on Edwards (1993) to be <59% (z1), 60–69% (z2), 70–79% (z3), 80–89% (z4), and ≥90% (z5) HR_{MAX}[275, 279]. Further explanations regarding metrics-terminology and definition are available in the VX Sport metrics glossary [280].

9.2.5 Statistical analysis

Normalised data cases meeting inclusion criteria were statistically analysed in SPSS. Descriptive statistics were reported as mean ± standard deviation (SD). Group differences were calculated using independent sample t-test. Normality of the distribution was assessed graphically and analytically with the Kolmogorov-Smirnov (KS) and Shapiro-Wilk (SW) test. Parametric analysis was prioritised for its superior power to reject the null-hypothesis and to ensure uniformity of statistical approach between outcome measures. Outcome measures for which specific groups showed non-nonorally distributed data were indicated, and Mann-Whitney tests were interpreted in complement. Homogeneity of variance was checked through Levene's test. Statistical significance was set at $p \leq 0.05$ and a conservative approach to interpreting differences between groups was taken by reporting the two-sided p-value. Standardised mean differences were also calculated as Cohen's d_s effect size (ES), using the pooled SD, to indicate *trivial* (-0.2>0<0.2), *small* (0.2 – 0.59), *moderate* (0.6 – 1.19), *large* (1.2 – 1.99), *very large* (2.0 – 3.99), and *extremely large* (≥4.0) magnitudes of difference [284, 285].

9.3 Results

Average playing time was 34.0 ± 8.0 (n=32), 31.0 ± 11.4 (n=36), and 57.9 ± 19.3 minutes (n=38), for first, second, and full match, respectively. Consequently, 24, 27, and 22 observations were included for analysis. Normalised game movement demands are reported in Table 38, differentiated by playing halves. Positional demands for forwards and backs are stated in Table 39. Valid within-positional group observations ranged depending on the outcome measure from 6 to 12 (forwards) and 6 to 9 (backs), with the lowest observations for RPE. Missing cases ranged from 0 to 10%, except for HR_{AVG} (30%) and RPE (40-50%). In V_Z and HR_Z, missing values ranged from 8 to 40%. Valid within-playing half observations ranged from 21 to 24 (1st half) and 20 to 27 (2nd half), except for RPE (15). Missing cases lied between 0 and 15%, excluding RPE (44%), and between 4 to 26% for V_Z and HR_Z.

Table 38 Mean game movement demands (normalised to 80 and 40 minutes)

	Full match		First half	Second half			
PERFORMANCE MEASURES	Mean ± SD	Range	Mean ± SD	Mean ± SD	*p*	[MW]	ES
Total distance (TD) (m)	5833.9 ± 536.8	[5018.8 – 7079.1]	2897.4 ± 229.7	2889.2 ± 307.6	0.92		0.03
Relative distance (RD) ($m \cdot min^{-1}$)	72.8 ± 6.7	[63.0 – 88.5]	72.5 ± 6.0	71.8 ± 7.7	0.75		0.10
Average speed (V_{AVG}) ($km \cdot h^{-1}$)	4.4 ± 0.4	[3.8 –5.3]	4.4 ± 0.4	4.3 ± 0.0.5	0.59		0.16
Maximal speed (V_{MAX}) ($km \cdot h^{-1}$)	28.4 ± 3.8	[19.9 – 35.9]	28.0 ± 3.8	27.2 ± 3.8	0.52		0.19
HIRD (m) (≥18 $km \cdot h^{-1}$)	410.3 ± 280.1	[29.6 – 911.5]	208.6 ± 125.7	218.6 ± 165.4	0.82		0.07
HSRD (m) (≥20 $km \cdot h^{-1}$)	274.5 ± 204.6	[0.0 – 645.7]	131.1 ± 86.5	154.5 ± 124.8	0.47		0.22
VHSRD (m) (≥25 $km \cdot h^{-1}$)	49.7 ± 58.6	[0.0 – 219.6]	26.9 ± 27.7	29.1 ± 45.6	0.85		0.06
Sprints	112.1 ± 48.5	[0.0 – 154.7]	68.4 ± 8.6	55.4 ± 23.6 [KS][SW]	0.02	[0.04]#	0.73
HIacc (≥3 $m \cdot s^{-2}$)	101.8 ± 34.3	[0.0 – 156.7]	58.9 ± 13.0	48.0 ± 17.1	0.02#		0.71
HIdec (≥3 $m \cdot s^{-2}$)	34.8 ± 16.8	[0.0 – 63.4]	19.5 ± 6.3	17.6 ± 8.2	0.36		0.27
Average heart rate ($\%HR_{MAX}$)	86.7 ± 3.4	[78.0 – 91.0]	87.8 ± 3.3	84.9 ± 4.0 [KS][SW]	<0.01	[0.01]#	0.80
ActivityLoad 3D rate (AL_{3D}) (AU)	3.1 ± 0.4	[2.3 – 3.9]	3.2 ± 0.4	3.1 ± 0.4 [KS]	0.17	[0.16]	0.39
Body Impacts	9.2 ± 6.2	[1.1 – 19.0]	4.7 ± 3.7 [KS][SW]	4.0 ± 3.3 [KS][SW]	0.49	[0.67]	0.20
Match RPE (6 – 20)	14.2 ± 0.8	[14.0 – 16.5]	-	-	-		

#Significant difference between groups; ES trivial (<0.2), small (0.2 – 0.59), moderate (0.6 – 1.19), large (1.2 – 1.99); [KS], [SW]: non-normal distribution (Kolmogorov-Smirnov/Shapiro-Wilk test p≤0.05); [MW] = Mann-Whitney test ($p \leq 0.05$)

209

Table 39 Positional mean game movement demands (normalised to 80 minutes)

	FORWARDS Mean ± SD	BACKS Mean ± SD	*p*	[MW]	ES
PERFORMANCE MEASURES					
Total distance (TD) (m)	5650.3 ± 452.9 [KS]	6058.2 ± 570.1	0.09	[0.06]∀	0.80
Relative distance (RD) ($m \cdot min^{-1}$)	70.5 ± 5.7 [KS][SW]	75.6 ± 7.0	0.09	[0.05]#	0.82
Average speed (V_{AVG}) ($km \cdot h^{-1}$)	4.2 ± 0.3 [KS][SW]	4.5 ± 0.4	0.08	[0.04]#	0.82
Maximal speed (V_{MAX}) ($km \cdot h^{-1}$)	27.0 ± 3.6	30.1 ± 3.6	0.07∀		0.86
HIRD (m) (≥18 $km \cdot h^{-1}$)	313.5 ± 217.4	562.4 ± 315.1	0.06∀		0.96
HSRD (m) (≥20 $km \cdot h^{-1}$)	205.9 ± 155.9	382.2 ± 236.4	0.07∀		0.93
VHSRD (m) (≥25 $km \cdot h^{-1}$)	27.7 ± 22.1	79.9 ± 79.6	0.11		0.97
Sprints	131.6 ± 12.8	90.7 ± 63.9 [KS][SW]	0.08	[0.17]	0.91
HIacc (≥3 $m \cdot s^{-2}$)	100.7 ± 20.7 [SW]	102.9 ± 46.2	0.89	[0.40]	0.06
HIdec (≥3 $m \cdot s^{-2}$)	31.3 ± 11.8	38.7 ± 21.0	0.35		0.44
Average heart rate (%HR_{MAX})	88.0 ± 2.7	84.6 ± 3.6	0.03#		1.11
ActivityLoad 3D rate (AL_{3D}) (AU)	3.3 ± 0.4	3.0 ± 0.4	0.12		0.70
Body Impacts	10.2 ± 7.3 [SW]	7.9 ± 4.5	0.37	[0.54]	0.38
Math RPE (6 – 20)	14.0 ± 0.0	14.8 ± 1.0	0.12		1.07

RELATVIE SPEED ZONES

V_{Z1} ($<20\%V_{TOP}$) (m)	2131.9 ± 488.0	2755.4 ± 128.9	0.005#		1.58
V_{Z2} (20-50% V_{TOP}) (m)	2781.9 ± 268.1	2526.4 ± 280.7	0.07∀		0.94
V_{Z3} (51-80% V_{TOP}) (m)	690.1 ± 488.3	633.8 ± 325.8 [KS][SW]	0.79	[0.86]	0.13
V_{Z4} (81-95% V_{TOP}) (m)	41.7 ± 40.6	34.4 ± 38.2	0.71		0.18
V_{Z5} ($>95\%$ V_{TOP}) (m)	4.4 ± 5.2 [KS][SW]	2.1 ± 4.6 [KS][SW]	0.34	[0.38]	0.48

RELATIVE HEART RATE ZONES

HR_{Z1} ($\leq 59\%HR_{MAX}$) (min)	0.00 ± 0.00	0.20 ± 0.43 [KS][SW]	0.31	[0.30]	0.81
HR_{Z2} (60-69% HR_{MAX}) (min)	0.38 ± 0.94 [KS] [SW]	3.51 ± 4.48 [KS][SW]	0.15	[0.15]	1.16
HR_{Z3} (70-79% HR_{MAX}) (min)	10.22 ± 7.89	17.83 ± 8.06	0.08∀		0.96
HR_{Z4} (80-89% HR_{MAX}) (min)	39.92 ± 8.22	37.59 ± 8.50	0.59		0.28
HR_{Z5} ($\geq 90\%$ HR_{MAX}) (min)	29.67 ± 14.73	20.64 ± 13.75	0.24		0.63

#Significant difference between groups; ∀Trend to significant difference between group; ES = trivial (<0.2), small (0.2 – 0.59), moderate (0.6 – 1.19), large (1.2 – 1.99); [KS], [SW] = non-normal distribution (Kolmogorov-Smirnov/Shapiro-Wilk test $p \leq 0.05$); [MW] = Mann-Whitney test ($p \leq 0.05$)

9.4 Discussion

This study investigated the total, partial, and positional match characteristics of U19 school-level RU competition. To our knowledge, this is the first investigation to describe RU matches for adolescents in the NZ educational pathway. The results indicated high general match demands, a performance drop from the first to second game half for select measures only, and meaningful differences between forwards and backs across various absolute and relative performance indicators.

9.4.1 Full match demands

As cohort-specific game characteristics are important for understanding within-competition dynamics and informing training practice, a general look at the overall demands is needed. The running demands of these NZ U19 showed near-identical TD and V_{AVG} to Australian national-level U16 (5.8 km, 4.3 km·h^{-1}) [119]. Although such distances are in line with rugby literature for international adolescent cohorts (~3.9 – 6.4 km), most, including elite-level players, covered less distance [16, 118, 121, 207]. South-African provincial-level U19 and English academy U18 backs, for example, travelled 4.5 km [16, 118], while a large sample of Australian school to elite-level U14 to U18 (15.9 6 ± 0.9 years) averaged 5.3 km [117]. In part, this is due to some youth matches spanning a shorter duration (60-70 min) [16]. Despite these shorter matches, these English school-level U16 and U18 demonstrated comparatively lower RD of ~68 and 66 m·min^{-1} as compared to NZ school-level players (~73 m·min^{-1}) [16].

The observed match distance and speed approximate those of senior cohort. English university-level backs, amateur to elite-level New Zealand seniors, and European Cup and PRO12 players all showed similar results (~5.7 to 6.1 km at ~4.1 to 4.6 km·h^{-1}) [110, 453]. To caveat, in many cases large variances exist within squads, thus overlap between players from various studies will generally occur. These general metrics provide a surface-level perspective, and more performance-specific data can provide further clarification. Of note is that NZ U19 between-player ranges (e.g., ~2050 m TD) demonstrated more homogeneity in running distance compared to various local, national, and international cohorts (i.e., SD 536.8 m vs. ≥853 m TD) [110, 453].

Repeated high-intensity efforts (RHIE) play an important role, as the ability to meet these often short-duration "worst case scenario"-demands can be performance-determining and has been associated with higher playing level [106, 111, 170, 453, 463]. Therein, Spanish U19 internationals covered greater HIRD (2.8 ± 1.5 vs 1.7 ± 1.0 m·min^{-1} at 18-20 km·h^{-1} and 4.6 ± 2.4 vs 3.4 ± 2.6 m·min^{-1} 274.5 at >20 km·h^{-1}) than this school-level cohort [464].

Aside from the substantial age difference (18.6 ± 0.5 years), which implies ~2.3 years of developmental progress, the Spanish cohort was an elite selection [255, 464]. As these measurements concern high-speed movement captured by different manufacturer-devices (10 vs 15 Hz), a part of the disparity in this outcome may be equipment-related [255, 465]. Furthermore, extraneous factors such as weather, competition, and game plan also play a role [282]. As seen between playing level and academy age groups, such discrepancies in age, anthropometrical development (body mass: 90.0 ± 10.6 kg; height: 181.5 ± 6.8 cm [464]), and training experience (6-10 hour per week; ≥ 4 years RU-specific training [464]) are likely to influence match performance outcomes [16, 459]. Conversely, U16 RL players (15.5 ± 0.7 years) competing in professional club and international matches showed lower HIRD (367.3 ± 155.2 and 398.3 ± 83.7 m, respectively), as did U20 Italian internationals with approximately 141 m above 17 km·h^{-1}, compared to 410.3 ± 280.1 above 18 km·h^{-1} for NZ U19 [460, 466] .

On a relative basis, this NZ cohorts' HIRD (~5.1 m·min^{-1}) approximated that of international performance U20 squads (~5.3 m·min^{-1}), and surpassed that of the seniors (~4.9 m·min^{-1} at >18.1 km·h^{-1}) [206]. However, across four senior professional to international competitions, HIRD was established to be higher (6.4 ± 4.3 m·min^{-1}) [27]. Comparison of HSRD (~3.4 m·min^{-1}) with that of English school-level U16 and U18 shows lower values (~1.3 – 2.8 m·min^{-1}), even for shorter match durations (60 to 70-minutes). A caveat is the threshold speed used with these English cohorts was higher (>21 km·h^{-1}), making direct comparison inapt. Furthermore, English U18 backs did achieve higher HSRD (4.5 m·min^{-1}) [16]. In senior play, internationals ran ~0.9 to 6.2 m·min^{-1} (>20.6 km·h^{-1}), positioning NZ youth in their mid-range, with ~3.4 m·min^{-1} (>20 km·h^{-1}) [452]. For VHSRD, NZ U19 tied with U18 French internationals (0.6 ± 0.7 m·min^{-1}), while surpassing U20 Italian internationals by more than threefold (~16.5 m at >24 km·h^{-1}) [460, 461]. However, higher values still have been found in club and international RL matches for talented U16 players (102.3 ± 86.8 and 62.5 ± 51.0 m) [466].

Further to RHIE, sprint count was substantially higher than what has been observed in elite-level RU senior Super 12 competition (18 ± 8) but V_{MAX} was considerably lower (~31 - 34 km·h^{-1}) [278]. For youth cohorts, only lower sprint rates (<1.40 ± 0.61) have been reported. Portillo et al. noted 0.22 ± 0.11 very-high intensity runs (i.e., sprint) for U19 internationals [464]. Hartwig and colleagues found a median sprint rate of 0.36 for U14 to U19 on various competitive levels [117]. And both school-level U18 and international U19 players have shown similar V_{MAX}, yet inferior to the our results, of respectively 26.6 ± 2.9 and 26.7 ± 2.8 km·h^{-1} [16, 464].

Such comparative differences might be associated with discrepancies in physical ability testing documented between NZ youth and international cohorts and supported by comparatively greater high running demands in NZ rugby sevens (7s) [383, 467]. However, technological differences in data collection, metric definition, and contextual factors, likely impact these results [241, 255, 280, 468]. Notwithstanding, these findings are in line with our high-end high-intensity speed and distance metrics reported earlier.

Regarding high-impact movements, Peeters et al. reported less HIacc (>2.5 $m \cdot s^{-2}$) for U18 and U20 internationals (0.5 ± 0.2 and 0.4 ± 0.1 $n \cdot min^{-1}$ vs 1.3 ± 0.4 $n \cdot min^{-1}$) [461]. Another international U18 squad of more comparable age (17.2 ± 0.5 years) showed ~26 HIacc and ~48 HIdec for full RL matches, which contrasts our findings showing the inverse ratio of HIacc to HIdec, and substantially more HIacc [113]. Despite a different make of microsensor device, the sampling frequency (100 Hz) and threshold value (>3 $m \cdot s^{-2}$) were identical. In addition to caution being warranted for accelerometry-based measurements and comparison between microsensor units, this might indicate some rugby code-specific variability [122, 227, 245, 246, 255, 256, 267]. Yet, more likely are the between-player and between-match variation of high-intensity activity, and level-dependent differences that have been documented in rugby [81, 246, 452]. Nevertheless, as professional and international senior players demonstrated 0.6 ± 0.2 HIacc and HIdec per minute, it seems evident that NZ U19 (1.3 ± 0.4 and 0.4 ± 0.2) play a highly dynamic game [27].

Accelerometer-based metrics have furthermore been shown to correlate highly with collisions in U18 RU [121]. Differences exist between junior (U12 – U16), amateur (U18 and senior), and elite (U18 and senior) playing levels, with a higher frequency of most collision match characteristics (tries and scrum excl.) for increasing age and playing standard [469]. Our results demonstrate a low impact rate that is nevertheless higher than for NZ U19 7s (0.12 ± 0.08 vs 0.07 ± 0.26) [383]. Higer values have been recorded for English, NZ, and South-African U16, U18, U19, and senior amateur, provincial, and elite-level players (263 ± 4 to 683 ± 295), and French U18 and U20 internationals (0.4 ± 0.2$\cdot min^{-1}$) [118, 461, 469]. Despite the capability of modern microsensors to discriminate between impact and running-based activities in RU, between-device comparison warrants caution due to potential differences in accuracy, sampling frequency, data processing, maintenance, the quantification and calibration of impact and high-intensity-related metrics, and inherent between-match fluctuations and contextual factors [241, 246, 252, 255, 396, 435, 470-472]. Consequently, VX SPORT™'s innovative approach to produce a meaningful impact perspective, as an alternative to often used "G forces", disallows direct between-study comparison [435].

In complement to the kinematic data, the physiological and psychophysiological markers indicate high demands on the cardiovascular system during NZ school-level matches. Junior RL players (U13-U15) have demonstrated higher playing intensities at younger ages and lower playing levels, relative to their capacity [473]. High absolute HR values for Spanish elite-level U19 competition have been reported to reach 189.0 ± 10.8 beats·min^{-1}, accompanied by blood lactate levels of up to 8.5 mmol·L^{-1} [464]. Previous research on Australian U19 also suggests that players spend most of game time between 85 to 95% HR_{MAX}, followed by 75-84% HR_{MAX} [474]. Our HR data supports these observations, suggesting these high match intensities are found internationally for this age cohort. Nevertheless, HR_{AVG} is higher than seen for U15, U16, and U17 playing for a professional Super League club in their respective competitions (79 – 83 % HR_{MAX}).

In a comparable context of school-level matches, NZ U19 have shown an HR_{AVG} of 89 ± 4 % HR_{MAX} for shorter-duration 7s matches [383]. The perceptual exertion, indicative of “somewhat hard” to “hard” physical strain, was higher than for U15 NZ 7s games (13 AU, RPE^{20}), yet markedly lower than professional RU games (8.2 ± 0.9 AU, RPE^{10}) [383]. This observation might be age and experience-related, and like in NZ 7s, it does not fully converge with HR intensity [383]. Such misalignment between HR and RPE can occur because of sport and context-specificity, as well as the methodological execution and the development of the Borg scale (cf. cycle ergometer) [264]. These markers should therefore be seen as an indication of global exercise intensity and interpreted in conjunction with other measures [268, 269, 414].

Measures of overall match load for RU have previously been reported as PlayerLoad™, from 417 ± 106 AU (i.e., 6.4 ± 0.7 AU·min^{-1}) in U18 to 550 ± 80 AU per match in professionals [16, 81]. The observed three-dimensional load metric in our study (AL_{3D}) indicated school-level RU is less taxing than 7s matches [280, 383]. Despite that, the full match analysis suggests that NZ school-level RU imposes high movement and physiological demands on players, beyond that typically seen for international adolescent players. Most match demands overlap with that of the senior and elite game, which suggests that the NZ educational pathway can prepare youth for the physical and kinematic strains of higher-level, and potentially international RU competition.

9.4.2 Half match differences

Investigations into performance differences between match halves, specifically, are scarce in the rugby codes with limited attention to RU [26, 112, 122, 144, 413, 466, 475-478]. These studies show that performance detriments occur throughout and between playing halves, especially for RHIE [26, 112, 413, 478]. Most kinematic, physical, and physiological markers are however, not significantly different between game halves or demonstrate within and between-study inconsistencies. Individual positional differences may also impact half-match performance changes [112, 478]. Increased performance has also been reported between match halves, albeit partly due to methodological considerations [477]. To our knowledge, data comparing match periods below the senior level in RU are not available [26, 122, 205, 282, 451].

In line with professional RL match-play, our data showed U19 maintained most kinematic outputs such as distances, speeds and V_Z, HIdec, and body impacts across both game halves [144, 475]. The acceleration-based markers are related, and by definition, their decrease concurs with the broader literature regarding fatigue-related performance drops in RHIE [26, 280, 478]. Sprint frequency (>6 $m \cdot s^{-1}$) and HIacc (>2.7 $m \cdot s^{-2}$) in professional forwards were shown to significantly decrease, but not in backs. However, varying definitions have been applied that makes direct comparison problematic [280, 478]. In contrast, Jones et al. found no decrease in HIacc with professionals using an identical threshold, notwithstanding a reduction in Player Load [112]. Playing level-specific and developmental differences between professional and school-level players might exist. However, no further kinematic measures like RD or HIRD were affected in these U19, unlike seen for some professionals [413, 478]. It is therefore reasonable to assume cohort, match, and competition-specific fluctuations play an important role in these cohort comparisons [27, 81, 110].

The observed fall in HR_{AVG} is in line to what was observed by Cunniffe and colleagues for elite-level players, and can likely be explained by the onset of fatigue and the following reduction in high-intensity output, such as sprints and HIacc [26, 108, 413]. In agreement with our observation, a decrease in HR_{AVG} was also seen in elite senior RL games, because of the reduced playing intensity during the second half [413, 479]. Conversely, a cardiovascular increase has been documented for international-level 7s, albeit for shorter-duration match haves [444]. Of note is that upkeeping the kinematic output during the second half, in terms of most measures in this U19 cohort, did not require a higher cardiovascular output. However, the ability to spend more time at the highest HR intensity has been associated with a higher playing level [480]. These findings consequently demonstrate the ability of NZ school-level players to maintain an even playing standard across game halves.

While the limited kinematic changes between game halves are in line with the literature, this cohort may have the potential to improve their kinematic output in the second match half by performing at a greater cardiovascular intensity.

9.4.3 Positional demands

The position-specific demands of the rugby codes have been extensively investigated. Most of the evidence has come from the senior game. [26, 101, 122, 282, 452]. Overall, RU backs tend to cover more TD and RD at higher V_{AVG} and exhibit greater HSR and sprinting demands while reaching higher V_{MAX} [112, 278, 282, 451]. Most of their distance is travelled walking or sprinting, relative to TD [26]. In turn, forwards tend to jog more at moderate intensities, demonstrate greater collision-related demands, and spend more time at higher HR [26, 107, 451]. When interpreting and comparing these movement demands, it is important to contextualise the arbitrary labels and absolute or relative categorisation of the represented measurement [26, 447, 451]. In concert with the relevant literature, the U19 backs in the current cohort covered more distance (~7%) at a faster pace (~7%) compared to forwards. As seen in senior matches, HIacc were similar for positional groups [107]. It is possible that the measurements at very high acceleration are less accurate and therefore ineffective at distinguishing differences [481]. Despite of this and counter to some evidence in senior RU, sprint count was meaningfully higher in forwards [107, 108]. This observation is likely due to its working definition[4] incorporating acceleration, duration, and absolute speed [280], as opposed to the more reductionist high-speed zone threshold crossing, as is often the case when using microsensor technology [107, 108, 122, 282]. As discussed in the literature, such an approach allows for low(er) speed (R)HIE bouts that are characteristic in various forwards positions, to be accounted for [26].

Also in conjunction with the senior game, absolute markers of HSR were substantially higher for backs compared to forwards (e.g., HIRD ~9% vs ~6% of TD) [112]. Position-specific tasks (rucks, mauls) and spatial constraints, together with faster acceleration and a higher V_{TOP} of backs compared to forwards are likely the greatest determinants for this finding [26, 98, 278, 407, 440]. Therefore, the position-specific movement characteristics demonstrate strong similarities with the senior game apart from impact-related activities. The magnitude-based difference in AL_{3D} between backs and forwards might nevertheless be an indication of this type of specific exertion [26, 451]. It is possible that, as collision-related match characteristics increase with age and playing level, differences between positions become more evident [469].

[4] Sprint: ≥0.69 $m \cdot s^{-2}$ to reach ≥10 $km \cdot h^{-1}$

When comparing within youth RU, our results align with data emphasising backs' roles being more HSR and locomotor-based than forwards' [461, 464, 474, 482]. Nuance is warranted, however. Akin to our findings, various studies established practically meaningful, yet not always significantly greater values for TD and V_{AVG} in elite-level U19 backs compared to forwards [461, 464, 474]. Of note, at the school level, U16 forwards have been reported to cover more TD than backs while differences for RD are unclear. Antithesis to that, U18 forwards were likely to cover less RD, but not necessarily less TD [16]. Then again, academy-level U18 forwards did cover less TD [121]. Further position-dependent discrepancies between school-level U16 and U18 are evident for absolute V_Z; U16 backs covered more distance than forwards in the highest two zones, whereas U18 backs did so only in the highest zone. In accordance, our data showed practically relevant differences in the highest absolute V_Z ($\geq$25 km·h^{-1}) and, in line with Portillo et al., the distances above 18 and 20 km·h^{-1} were clearly greater for backs [464]. Differences in V_{MAX} also concur with elite-level U19 data [464].

Further to the positional differences in locomotion, the relative speed data confirmed that backs walk more distance and forwards tend to jog more [26]. Counter to the general notion, these U19 backs did not perform more HIR than forwards when accounting for their V_{TOP}. The distinguishment between absolute and relative thresholds is therefore essential to make, as V_Z are the most commonly collected metrics by rugby practitioners and should not be conflated with high intensity? [447, 468]. Predefined absolute "sprinting" or HSR thresholds are unlikely to accurately represent individual players' actual equivalent exertion in different populations [26, 146, 352, 448]. This distinction might be particularly relevant during the developmental stages [277].

Our results for both absolute and relative distances in V_{Z1} (45% / 38% of TD for backs/forwards) and V_{Z2} (42% / 49% TD), were near-identical to that of Premiership backs who walked more than forwards (2999 m (46% TD) vs 2190 m (37% TD)) but jogged less than forwards (2559 m (40% TD) vs 2616 m (46% TD)) [24]. Further in support of our data, Venter and colleagues established U19 semi-professionals spent most of game time either walking and jogging, with backs spending more time walking than forwards (54-60% vs 42-47% of match time) and forwards spending more time jogging than backs (24–26% vs 16-20%), depending on exact positions [118]. These observations strengthen the kinematic data which suggests NZ U19 movement demands converge towards elite and senior-level match-play.

When it comes to impacts, the results do not support prior U18 elite-level and U19 provincial-level evidence that forwards have higher tackle, collision, and impact counts than backs [118, 121]. This conflict is likely due to the specific metric used [435]. Aside from semantic and measurement differences, contextual differences may be influential, and accuracy issues can occur during high-magnitude accelerations [396, 481]. Nevertheless, our AL_{3D} favoured forwards (moderate ES), which aligns with English academy forwards (U16, U18) showing a higher player load than backs [16, 121]. Various forms of player load measurements, such as Player Load™ vs Player Load™ Slow [16, 121], can differentially inform on high/low-speed, high/low-magnitude acceleration, yet intense exertion, which might not cross high-impact thresholds. These different forms of load can be position-specific. Therefore, it is of the essence to acknowledge this variety and purposefully consider the most adequate measures within each context. [16, 26, 435]. Additionally, differences within RU youth populations could be underpinned by specific cohorts' contexts, like opposition and competition level [241, 453].

The physiological results indicate that forwards have a higher exertion, which supports the findings of Deutsh and colleagues [474]. However, Portillo and colleagues did not find differences in HR_{AVG} between elite-level U19 backs and forwards, in contrast to our results [464]. Nevertheless, contact-related rugby activities, which are more prominent in forward roles, have been associated with increased HR_{AVG} [26, 483]. Our data further demonstrates that backs and forwards spent most of game time (~73 – 86%, respectively) at high cardiorespiratory intensity (≥80% HR_{MAX}), and especially between ~80 – 90% HR_{MAX}. These data have been borne out in both elite-level youth and senior data, with U19 forwards spending significantly more time at higher HR (85 – 95 % HR_{MAX}) than backs [108, 474].

A comparison with the highest level shows senior elite players spent proportionally more time above 90% HR_{MAX} (~41 – 51% vs ~26 – 37%) than seen in our investigation [108]. This observation indicates younger players might not have the same capacity to sustain anaerobic work. In agreement with elite-level U19 data, relevant differences seem to emerge within this NZ cohort, with backs spending substantially longer in aerobic (<80% HR_{MAX}), and forwards in anaerobic conditions (≥90% HR_{MAX}) [474]. A greater engagement of forwards in RHIE like rucking, mauling, and possibly collisions, is generally associated with this discrepancy [104, 107, 108]. AL_{3D} seems to support this notion to a moderate degree. Consequently, the physiological data seems to concur with the limited evidence regarding (elite) youth and senior play, of high cardiovascular taxation that is activity-dependent, and therefore position-specific. Notwithstanding, youth players show growth potential for submaximal to maximal cardiovascular performance.

In summary, the positional kinematic, physiological, and physical differences in our investigation largely converge with senior and elite-level youth competition. Discrepancies exist with the school-level data. Forwards seem to have greater cardiovascular demands characterised by lower absolute speed locomotion, while simultaneously performing at higher relative speeds. In turn, backs tend to display greater HSR and walking demands. Forwards perform more sprints than backs, possibly linked to the nature of their tasks, and do not necessarily demonstrate more impacts. Overall match load seems to be slightly higher in forwards.

9.5 Conclusion

This study presents the full, half, and positional match demands for a NZ first XV school-level RU squad. The kinematic, physiological, and physical demands placed on these U19 rugby players aligns with and can surpass that of international elite-level junior and senior matches. Match-play is characterised by dynamic high-volume and high-speed running, with low body impacts. Performance is maintained to a high degree throughout both game halves, with a decrease in HR and only limited decreases in high-intensity movements. Positional differences are evident with forwards accruing more total load at moderate speeds with a higher HR, and backs spending more time at aerobic intensity and reaching greater absolute speeds. However, relative efforts and impacts contradict general notions, as forwards show higher relative running demands than backs, and body impacts may not discriminate between positions. Measuring practices within RU need to be standardised to optimise meaningful comparison between cohorts. The NZ educational pathway appears to adequately prepare NZ youth for senior and possibly elite-level RU competition. Further research into RU youth is required to strengthen these conclusions.

9.6 Practical applications

NZ school-level RU competition is characterised by high movement demands with potentially lower body impacts. This information can be used to ensure youth players are conditioned to perform at high volume and high intensity, primarily. Practitioners should be aware of the differences between forwards and backs, with attention to both absolute and relative development, aiming to maximise time at HIE (≥90% HR_{MAX}) for the duration of the full game. Training practice should reflect intermittent HSR for backs, and more continuous lower-speed but RHIE for forwards. In addition, practitioners should be cognisant of the potential impact-related discrepancy between youth and senior (semi-) professional match-play and ensure sufficient adequate exposure to prepare youth players for the rigours of higher-level rugby.

9.7 Limitations

The sample used in this study was of modest size and for a small number of matches. Data points for specific groups and measurements are outlined and should be considered when interpreting the results. Furthermore, positional differences are a function of the metrics used and can be relative to individuals' maxima. Inconsistencies in measuring equipment, definitions, and methodical approaches make it therefore difficult to compare microsensor data between studies [145, 468]. In addition, the impact of specific cohorts' contexts on misalignment of these data is not yet fully understood; e.g., differences between backs and forwards could be heavily influenced by any combination of the exact chronological age and developmental stage, the level of competition and opposition, playing strategies, match-to-match variability, as well other contextual factors like geographical population-based differences in RU-specific fitness [81, 110, 170, 241, 407, 440, 459, 460, 467, 484]. These factors might have a larger impact in lower-level competition where the playing standard is less uniform. Furthermore, individual positions have been shown to differ in demands, which implies a general positional divide could blunt or exacerbate specific match demands [24, 112, 118, 352]. More investigation into this population is required to strengthen and extrapolate the current study's findings.

KEY POINTS

- **Point 1** – New Zealand school-level RU match demands are high-intensity and high-volume, comparable to elite-level and senior competition. Youth U19 players uphold this high-level output throughout the full game.
- **Point 2** – Forwards and backs need a differentiated training approach to reflect differences in match demands regarding anaerobic and aerobic cardiorespiratory requirements, distances travelled, HSR, and sprints.
- **Point 3** – Youth RU competition warrants investigation into relative measures in addition to absolute measures, and attention is required towards standardising sprint, accelerations, and impact definitions. These kinematic, physiological, and physical measures challenge the interpretation of commonly accepted positional match demands.

SECTION III

THESIS DISCUSSION

CHAPTER 10

Thesis discussion

This doctoral study was conducted to enhance the understanding of the application of small and large-sided games (SSG and LSG) to rugby union (RU) youth. Specifically, the effects of design variables on kinematic, physiological, and physical performance measures were investigated. This thesis provides a novel contribution (1.3.3 Importance for advancing knowledge) that shows the structural limitations of the relevant body of knowledge impinge on the ability to effectively and optimally design SSG to prepare youth players for the demands of their competition. This doctoral study also provided clear evidence for the first time to support the often assumed and anecdotally supported premise that SSG are popular training forms among RU practitioners on all levels of play, especially in New Zealand (NZ). Furthermore, we have established practically relevant SSG formats and demonstrated the importance of the elemental design variables, such as player number, pitch size, and bout sequencing, in youth age categories. This investigation for the first time offers concretely applicable prescriptive guidelines for adolescents based on the match demands determined for male NZ secondary school-age players. Our research indicates that the standardised application of popular SSG formats may not prepare youth players optimally for the high demands of NZ school-level RU and rugby sevens (7s) competition. In addition, the use of specific measurements, such as relative speed, indicate that positional differences may challenge the current understanding in match-play. Consequently, this novel information can be used to optimise RU youth training for cohort-specific competition demands. Therefore, this discussion will provide a synthesis of the individual research findings, answer the research questions, provide practical applications, delineate the limitations, and outline future research directions.

10.1 Research synthesis

The research premise

Preliminary review (Chapter 2) of the literature in this doctoral study outlined the socio-historical context of rugby and its contemporary significance globally as well as in NZ society. This review furthermore described the characteristics of rugby game-play as high-intensity and intermittent of nature, alongside providing initial evidence for the relevance of game-based training (GBT). Small-sided game-play had been extensively investigated in the football codes but the knowledge regarding SSG^{RU} was lagging [46, 59, 96, 97, 485]. The premise of GBT is its assumed widely-spread use in high-intensity intermittent field-based teams sports such as rugby due its ability to contextualise training and concurrently offer physical, technical, tactical, and socio-affective benefits [97, 175, 176]. However, scientific evidence regarding its application in the field was lacking.

The practice

This doctoral investigation (Chapter 5 and Chapter 6) included a pioneer study that established that SSG^{RU} are prevalent, showing that 85% of practitioners across playing levels and player age categories regularly (at least once per three training sessions) apply SSG to improve technical skill and fun primarily, as well as physical conditioning and tactical training [349]. While three, five, and seven-a-side were the most popular formats, no clear consensus on relative pitch size labels (small, medium, large) were established [391]. Nearly half (47%) of practitioners used three SSG bouts that generally lasted between two and ten minutes with a 1:1 to 5:1 work-rest ratio, but the design of SSG was shown to be dependent on practitioners' characteristics. Higher-level practitioners adhered to the scientific evidence more often, using shorter touch-rule games for physical conditioning. In contrast, lower and school-level practitioners were more often inclined to apply longer-duration tackle-based games for fun experience and skill-training. Considering the cohort-specificity established in our study, practitioners' performance contexts need to be accounted for. As such, this thesis provides evidence that practitioners' professional role and experience, target player age group, competition level, player sex, and geographical location will determine how SSG are designed in practice to prepare players for their competitions [391].

Match demands

The scoping literature review (Chapter 2) showed that the competition demands of senior and especially elite-level RU players had been studied more extensively than for youth. The evidence revealed a multi-facetted training approach is required with differentiation between specific cohorts regarding level of competition, age category, and playing position. Thereby, Read et al. (2017) provided preliminary evidence that specific performance differences can occur between youth age categories, as well as between playing positions [16]. Therefore, this thesis documented that most kinematic, physiological, and physical demands of NZ secondary school-level RU matches (Chapter 9) converge towards and can surpass the demands of senior and elite-level competition. School-level U19 compete with high intensity and high volume sustained throughout the full game, apart from a decrease in sprints and HIacc (Table 38). Players travelled 5.8 kilometres and rated their perceived match exertion 14 out of 20 RPE. Up to 70 game minutes (88%) were performed above 80% HR_{MAX} and average speeds reached up to ~76 $m \cdot min^{-1}$, which is higher than their international peers [16]. In contrast, impacts were comparatively lower, potentially, as metric definitions were not uniform [118, 461, 469]. Notwithstanding these high intensities, approximately 87% of match distance was covered at low speeds (<50% V_{TOP}) (Table 39). Thereby, we established that positional differentiation in training approach is necessary to reflect greater distance and intermittent speed demands for backs, including high-intensity and high-speed running. In turn, forwards showed more continuous and greater cardiorespiratory demands. However, the incorporation of nuanced sprint and impact definitions in this investigation, in addition to relative HR and speed zones, indicated that forwards can perform at lower absolute, yet higher relative movement speeds and cardiovascular intensities than backs. Furthermore, forwards could sprint more than backs and do not necessarily experience more impacts. This information should ultimately be used to quantify cohort-specific player match loads.

As research on youth 7s match demands was limited to van den Berg et al. (2013) and Clarke et al. (2016), and school-level competition had not been documented, this doctoral study (Chapter 8) established the match demands of NZ school-level 7s competition [93, 115, 434]. Our novel research showed that 7s matches in a national tournament have an explicit and more continuous high-intensity character that surpasses that of fifteen-a-side youth matches [383]. Kinematic performance was determined to be notably greater in relative terms, with more running at medium and high speeds, as demonstrated by RD (~111.4 vs 72.8 $m \cdot min^{-1}$), sprint rate (~3.0 vs $1.4 \cdot min^{-1}$), HIacc (~3.0 vs $1.3 \cdot min^{-1}$), and HIRD (~18.0 vs 5.1 $m \cdot min^{-1}$) (Table 35). However, physical performance showed a lower impact rate (~0.07 vs $0.12 \cdot min^{-1}$) and RPE (13 vs 14 AU).

The shorter game duration (14 vs 80 minutes) might be influential in this perceived exertion. Evidently, 7s players accumulated less TD (~1.6 km) as compared to RU matches (~5.8 km) because of said game duration. This investigation also determined that youth 7s players walked proportionally less than in RU (~27% vs 41%TD) and jogged more (~50% vs 46% TD), giving 7s matches a less intermittent and more continuous high-intensity character (Table 36). Consequently, kinematic loading resulted in a greater ActivityLoad 3D rate of 4.9 vs 3.1 AU for 7s, as well as a greater physiological loading of 90% vs 87 % HR_{MAX}. Of note is that 90% of game time was spent above 80% HR_{MAX}, and up to 58% of game time above 90% HR_{MAX} (Table 37), further establishing youth 7s high-intensity profile. Parallel to the comparison made in RU, these continuous running demands of NZ youth 7s were greater than what has been observed in senior 7s competition on the state, provincial, and in various elite-level international cohorts. However, here too, impact frequency seems lower, albeit potentially due to differences in operational definitions. In addition to these comparisons, our investigation showed that there are in fact significant differences between age categories, as younger 7s players (U15) experienced greater movement demands than older 7s players (U19) (Table 35). This observation is in line with observations for select performance measures between RU adolescent age categories and positional groups [16]. Exemplary of these specific demands are greater RD in 7s matches for U15 compared to U19 (~116 vs 108 $m \cdot min^{-1}$), which in turn were greater than for U18 backs and forwards in RU (~76 and 71 $m \cdot min^{-1}$). Similarly, sprint rate was the greatest for U15 ($3.2 \cdot min^{-1}$), followed by U19 ($2.8 \cdot min^{-1}$) 7s players, and U18 forwards (~$1.7 \cdot min^{-1}$) and backs (~$1.1 \cdot min^{-1}$) in RU. The competition and cohort-specific demands established in this doctoral study therefore require consideration in training.

Small-sided games

Within this training approach, the literature suggests SSG can contextualise competition demands and offer a practically convenient training method (Chapter 2). However, the research was scarce and lacked uniformity, providing scant evidence that game-based formats with various designs could improve performance. This paucity was exacerbated in adolescents, with no evidence for youth outcomes which precluded the ability to draw strong conclusions about the effects of design variables on kinematic, physical, or physiological parameters. These gaps identified in the body of knowledge warranted more in-depth investigation. As such, the systematic literature review (Chapter 4) originally identified one longitudinal investigation (chronic outcome) [86] and six cross-sectional studies (acute outcome) [28, 87, 88, 149, 306, 343] relating to SSG design factors in function of physical, physiological, and kinematic outcome measures.

This limited body of knowledge demonstrated a disparity in study methods, SSG designs, and measurements. Within this body, study quality ranged from 52% to 98%. However, risk of bias (RoB) assessment established that five out of seven initial studies were at critical RoB, and a further two were at moderate risk. The implications according to ROBINS-I methodology (Attachment 6) are that two studies provided sound evidence for a non-randomised study but cannot be considered comparable to a well-performed randomised trial, but five studies are objectively too problematic to provide any useful evidence and should not be included in any future synthesis of the literature. These findings are in line with prior systematic research outlining low methodological quality in SSG systematic reviews and meta-analyses [96, 97]. A follow-up investigation showed developments were made during this doctoral study resulting in seven additional publications [97, 283, 344-348]. In line with previous research however, this evolution showed a similar heterogenous methodological character.

The current state of the evidence demonstrates SSG^{RU} can be used in specific circumstances to condition RU players. Average HR have been documented as high as 89% of HR_{MAX}, while concurrent reports of up to 80% of game time spent at or above, and more than 71% of game time spent below 85% HR_{MAX} form conflicting evidence [87, 88, 283]. In complement to that, most of SSG training session time was reported to be executed at 30-39% of peak movement intensity [346]. Furthermore, RPE has ranged from 13 to 17 on the Borg-scale [88]. In turn, speeds have been reported to rise to ~121 $m \cdot min^{-1}$, with peak epoch-demands up to ~250 $m \cdot min^{-1}$ [346]. Varying frequencies and degrees of impacts, as well as variable technical and tactical behaviours have also been documented [87, 149, 306, 345, 347]. More recent evidence suggests that SSG can be adapted to obtain targeted technical and tactical outcomes to suit positional groups while considering inherent variability when applying SSG over time [345, 347]. Ultimately, as confirmed by Zanin et al. (2021), the limited availability of cohort-specific research and the disparity in methodological approaches, allow for the conclusion that GBT has the potential for physical conditioning in a range of RU cohorts consisting of mostly (elite) senior players [86, 97]. However, optimal match preparation might require SSG to be complemented by traditional endurance training and high-intensity interval (HIIT) training [28]. Further to that, modulating SSG can have physical, technical, and tactical effects [97]. To modulate the potential conditioning effect, the limited evidence suggested that higher acute kinematic and physiological loading can be achieved with lower player numbers and larger pitches. However, differentiation is critical as outcome measures such as V_{PEAK} and HR might not be as readily influenced as compared to other kinematic, physical, and physiological performance outcomes [87, 88, 97].

The available evidence clarified that GBT outcomes are the result of complex interactions between SSG design variables, measures, technologies used, and the targeted players. A recent systematic review of the rugby football codes supports our findings that there is limited research to guide SSG design, especially in RU, with no youth included [97]. In addition to the inconsistent and suboptimal study quality of the available, varied, and context-bound study results, this doctoral study was the first to show that the original body of knowledge is at critical RoB (Table 13) [88, 343]. Biases due to measurement of outcomes, missing data, deviations from intended interventions, and classification of interventions were identified, and especially bias due to selection of participants and confounding were found to be problematic. These methodological limitations imply that the information presented in the available body of knowledge is largely unsuitable for broad extrapolation. Furthermore, our investigation indicated the absence of relevant design elements such as bout effects and outcome measures such as relative speed and injury incidence (Table 10). In response to these observations, our methodological approach has integrated these outcome measures and adopted a form of standardisation of SSG design and randomisation of participant allocation.

In aim of clarifying how SSG design differentially emphasises physiological, kinematic, and physical performance measures, this doctoral study for the first time standardised SSG application in NZ secondary school-level age categories. Players were randomised to touch-rule SSG formats played on proportional pitches (875 m^2 (S), 1750 m^2 (M), 3500 m^2 (L)) [5], without coaching. Relevant understudied design and outcome variables such as bout effects, relative speed zones, HR_{AVG}, and injury incidence were incorporated. This investigation established that the elemental design factors player number (3, 5, 7-a-side), pitch size (S, M, L), and playing bouts (1, 2, 3), as well as age group (U14, U15, U16, U18), influence overall performance in SSG^{RU} (Chapter 7). Across four different RU youth age categories, we determined that player number and pitch size are the main drivers of SSG performance outcomes, followed by the effect of age group and bout sequencing (Table 28). Of note, is that the established design factors mutually modulate each other's influence, such that simultaneous consideration of these factors is indicated when designing SSG. In addition to the importance of age groups, specificity of target outcome measures was established, meaning identical SSG formats can differentially impact performance metrics across age groups. As a consequence, blanket statements regarding groups of outcome measures are suboptimal and should ideally be limited to specific outcome measures and populations, or at least framed with adequate nuance.

[5] Small (S)= ⅛ pitch (25x35 m= 875 m^2), medium (M)= ¼ pitch (35x50 m= 1750 m^2), and large (L)= ½ pitch (50x70 m= 3500 m^2)

This doctoral thesis presents a more nuanced perspective than the notion commonly accepted in the literature. Our investigation showed that, when considering the isolated effects, in line with the literature, lower player numbers tend to maximise the core movement and cardiovascular demands in youth SSG^{RU}. However, larger pitch sizes in contrast, only reliably maximised kinematic demands and RPE. Physiological performance measures such as HR_{AVG}, HR_{MAX}, and time above 90% HR_{MAX} were more resistant to pitch size changes (Table 29). The implication of these physiological markers may be that, more so than the available space per player, minimal options for player-interaction (i.e., 3v3) distinctly increases cardiorespiratory strain. Additional nuances exist whereby significant changes in performance may only correspond to player number and pitch size changes that surpass a minimum threshold; e.g., between 3v3 and 5v5 but not between 5v5 and 7v7 (e.g., V_{AVG}), or between S and M pitch, but not between M and L pitch (e.g., V_{MAX}). Consequently, changes in specific outcome measures do not necessarily occur linearly for SSG formats (i.e., 3, 5, 7-a-side, or S, M, L pitch) (Table 29). Furthermore, some variability is evident when considering a larger array of performance measures, whereby some measures respond significantly to every, some, and no format changes within kinematic, physiological, and physical categories (Appendix 10: Youth SSG general performance measures (imputed values - R), Appendix 11: Youth SSG relative speed zones (imputed values - R), and Appendix 12: Youth SSG relative heart rate zones (imputed values - R)). Thus, as previously stated, outcome measure-specificity in GBT is of the essence.

The novel and holistic approach in this doctoral study, whereby player number and pitch sizes were integrated, allowed for direct comparison between specific formats. These comparisons in youth concretises the generalised notion lower player numbers and larger pitches illicit greater loads; the greatest physical, physiological, and kinematic demands were seen for the largest individual playing area (3v3-L), and the lowest demands with the lowest individual playing area (7v7-S) (Table 34). However, here too, performance measure and age group-specific variability are evident in some cases. For example, practically meaningful differences were observed for time in HR_{Z5}, with ~27% (U14, 3v3-S), ~43% (U15, 3v3-S), ~9% (U16, 3v3-L), and ~21% (U18, 3v3-S) of SSG time spent above ≥90% HR_{MAX}. In addition, HIacc (3v3-S) and HIdec (3v3-M and 5v5-L) are not maximised with the largest relative playing area. Age cohort-related differences thereby seem to demonstrate irregular evolutions, across performance measures. Similar observations were previously documented for match demands in English RU youth [16]. Of note is that statistical overlap between formats applies for most performance measures. Our research indicated that a relative playing area between circa. 350 and 583 $m^2 \cdot player^{-1}$, and for some measures as little as 175 $m^2 \cdot player^{-1}$, can illicit similar kinematic, physiological, and physical performances in all age groups.

The observation of such a *'buffer'* interval allows for flexibility in the application of SSG formats to suit the practitioners' specific context. This flexibility is important when taking into account the differentiated practitioners' performance contexts [391]. Despite this range in playing area, maximising player number (i.e., 7v7-L= 250 $m^2 \cdot player^{-1}$) could still incur a performance-detriment, as this format showed statistically lower results than the optimal SSG format for 11 out of 15 main performance measures and for V_{Z3} and V_{Z4} (Appendix 10: Youth SSG general performance measures (imputed values - R) and Appendix 11: Youth SSG relative speed zones (imputed values - R)). These observations indicate that where more interactional possibilities exist between players, physical, physiological, and kinematic performance diminishes.

This investigation has furthermore established that the structure with which SSG are applied to youth players is important. Across physiological, physical, and kinematic performance measures, greater demands were generally observed when considering average playing bouts (four minutes) as compared to full SSG (18 minutes). This discrepancy is to be expected considering the three-minute-activate-recovery phase between playing bouts. However, our investigation shows initiatory observations revealing that the execution of work and rest phases in standardised SSG can differ between various youth age groups, despite identical instruction. The preliminary indications are that younger players (U14) demonstrate lower running demands and simultaneously lower perceived exertion, yet not necessarily lower average cardiorespiratory demands (Table 34). Age groups should therefore be considered individually, and it is indicated to use SSG bouts as the basis for measuring high-intensity and high-quality work.

In this regard, this study has shown that Bout 1 has a benchmark function compared to following bouts, during which youth players most often perform better (Table 30). However, these distinctions are only evident for select performance variables, and most often serve to exacerbate the results in SSG formats with the most extreme relative playing area (e.g., 3v3-L and 7v7-S) (Appendix 14: Youth SSG formats bout differences – General performance measures (imputed values R)). Of note is that accumulating bouts consistently and reliably elevates RPE in all SSG formats (Table 30); thus, youth players as a whole experience greater psychophysical load for additional SSG bouts after Bout 1. Age group-related differences are, however, also evident (Appendix 14: Youth SSG formats bout differences – General performance measures (imputed values R), Appendix 15: Youth SSG formats bout differences – Speed zones (imputed values R), and Appendix 16: Youth SSG formats bout differences – Heart rate zones (imputed values R)).

The evidence presented in this thesis demonstrates that optimally designed standardised, yet elemental SSG, including three bouts of four minutes of 'touch' with active recovery, surpass the demands of fifteen-a-side youth RU competition in terms of RD, HIRD, HSRD, VHSRD, HIacc, and HIdec, on a per-minute basis. The players' kinematic load (AL_{3D}) was also greater in the optimal SSG, and players rated their perceived exertion higher than match RPE. In contrast, SSG only approached competition V_{MAX} (~26.6 vs 28.4 $km.h^{-1}$), but whole SSG or individual bouts did not meet match sprint frequency, nor HR_{AVG} and HR_{Z5}. Despite youth demonstrating an average cardiovascular intensity of ~79 to 85% HR_{MAX}, and only 1.1 ± 1.2 minutes per bout and 4.3 ± 3.8 per SSG (~24%) spent above 90% HR_{MAX}, maximal HR were seen to rise, up to ~96 %HR_{MAX}.

In contrast to the 15s match comparison, these elemental SSG fell short on all measures except RPE, when comparing to youth 7s competition. However, relative per minute, the optimal SSG bout approximated 7s demands for V_{MAX} (~26.6 vs 27.6 $km.h^{-1}$), AL_{3D} (4.8 vs 4.9 AU), HIdec (0.98 vs 1.16), and surpassed it for HIacc (~3.05 vs 2.99). Impact frequency was found to be lower in touch SSG than in competition and can consequently be considered a relatively safe training form, as evidenced by the 59.8 per 1000 player-hours "injury" incidence (i.e., physical discomforts), buttressed by the absence of any physical incidence requiring medical attention.

In addition to these observations, data from a pilot case study suggests that, despite the established shortcomings for optimal match preparation, youth players produce similar kinematic and physiological outputs to elite-level players (ADDENDUM: An elite-level small-sided game pilot case study). In optimised formats such as 3v3-L, select measures such as TD (~443 vs ~436 m), HIRD (~39 vs ~45 m), and HR_{AVG} (85% HR_{MAX} both) are similar, and even surpass those of international RU players (Table 41). However, elite players may demonstrate different playing dynamics towards various SSG format, as compared to youth, such that the highest values are seen in different formats to those in youth (e.g., ~456 m TD for elite players vs 400 m TD for youth players, in 3v3-M). Furthermore, this preliminary data indicates that elite-level players may execute SSG '*smarter'*, and may be selective with their efforts, as select maximal kinematic outputs were greater in international players, such as for RD (~115 vs ~107 $m \cdot min^{-1}$), V_{MAX} (~26 vs ~24 $km \cdot h^{-1}$), sprint rate (~5.1 vs ~2.9·min^{-1}), and HIacc (~19 vs ~12). Despite a greater AL_{3D} (~5.5 vs ~4.8 AU), and higher perceived exertion (8.4 RPE^{10} vs 13.6 RPE^{20}) in international players, HIRD (~39 vs 45 m) , HSRD (~30 vs 31 m), and VHSR (~ 7 m both) were similar between cohorts. These pioneer data warrant further investigation to establish a comprehensive developmental pathway, from youth to becoming an elite rugby player.

Using these elemental SSG differentially, youth RU training should aim at intermittent high-intensity workouts. Youth rugby 7s-specific training should target continuous high-intensity cardiovascular and running performance, with special attention for U15. Practitioners should furthermore consider that youth players perceive SSG loading differentially as very light to hard (RPE 9-16), age group and format-depending, which may surpass that of competition matches. The investigated SSG formats can elicit a general conditioning stimulus and near-maximal peak HR, yet they do not inherently provide an adequate cardiovascular stimulus for optimal rugby-specific match conditioning.

In conclusion, this thesis provides novel evidence that SSG are a useful training method for youth RU players. The benefits entail a representative, sport-specific, and practically feasible manner of targeting competition demands. Standardised SSG, delivered as presented in this thesis, can be used for general conditioning in a game-based environment, and to safely prepare youth players for most kinematic demands of RU competition. However, these elemental SSG do not inherently and optimally stimulate all physical, physiological, and kinematic characteristics and fall short of most rugby 7s competition demands. We therefore recommend that practitioners use a variety of these standardised SSG formats to target and monitor specific outcome variables of interest, and to elaborate on this research by applying best-practice and research-informed constraint-manipulations to optimise the stimulation of targeted training variables.

10.2 Conclusion

The knowledge provided within the context and the limitations of this doctoral investigation, allows us to formulate answers the research questions posed at the beginning of this study.

1. **How do practically relevant rugby union small-sided game formats alter physical, physiological, and kinematic variables?**

   a. Which SSG formats are applicable to and valuable in practice?

      This doctoral study has established that a variety of SSG formats are widely applied in practice, across playing levels and age categories. Of these formats, 3v3, 5v5, and 7v7 are the most popular among RU practitioners, and are most often played with touch rules on higher playing levels and tackle rules on lower playing levels.

   b. What is the effect of player number on HR, GPS, and RPE?

      An increase in player number tends to decrease HR, GPS, and RPE-related outcomes in SSG. Important nuances include that differences in outcome variables are most often evident between the lowest player number (3v3) and higher player numbers (5v5 and/or 7v7). Select performance measures such as sprint frequency show greater resistance to change through player number manipulation than others. However, differences are more evident for isolated work bouts than for whole SSG, which integrate active recovery bouts.

   c. What is the effect of field size on HR, GPS, and RPE?

      An increase in field size tends to increase GPS and RPE-related outcomes in SSG. Importantly, HR measures do not increase in isolation as pitch size increases. Player number manipulation holds a dominant influence to modulate HR measures. Further nuance includes the observation that differences in kinematic core performance variables occur more regularly when doubling field size than for player number alterations. Select performance measures such as sprint frequency show greater resistance to change through pitch size manipulation than others. However, these differences are more evident for isolated work bouts than for whole SSG, which integrate active recovery bouts.

d. What is the effect of SSG repeated bouts on HR, GPS, and RPE?

Repeated bouts tend to challenge youth rugby players in a few SSG formats such as 3v3-L and 7v7-S; players perform better in Bout 1 than in subsequent bouts on a substantial yet select number of HR and GPS-related measures, when relative pitch area is most extreme. In contrast, repeated bouts cause greater perceived exertion in all SSG formats.

2. How do the demands of selected game formats change for school-age male cohorts in New Zealand rugby union?

In general, formats with larger individual playing area and repeated bouts increase physical, physiological, and kinematic loading. Nuances exist between 3v3, 5v5, and 7v7 formats on S, M, and L pitches for youth age categories. In addition to being format-specific, these differences are outcome measure-specific. Consequently, differences do not uniformly nor linearly evolve between U14, U15, U16, and U18. There are preliminary indications that SSG are executed differently by younger players (U14), who show lower work phase-running, cardiorespiratory demands, and perceived exertion, relative to their rest phases, when compared to older players (U15-U18).

3. **What are the physical, physiological, and kinematic characteristics of full-sided games in school-age male cohorts of New Zealand rugby union youth competition?**

Secondary school-age male players competing in NZ, play with high intensity and high volume that can surpass the demands of senior and elite-level competition in terms of kinematic, physiological, and physical demands. Although most of match distance (87%) is covered at low speeds (≤50%V_{TOP}), average speeds reach ~76 m·min^{-1}, and up to 70 game minutes can be performed above 80% HR_{MAX}.

Rugby 7s matches in a national NZ tournament have an explicit and more continuous high-intensity character than that of NZ fifteen-a-side youth matches. Ninety percent of game time is spent above 80% HR_{MAX}, and up to 58% of game time above 90% HR_{MAX}. The kinematic demands are also notably high with speeds of ~111.4 m·min^{-1}, sprint rates of ~3.0 ·min^{-1}, and ~18.0 m·min^{-1} of HIRD, which can surpass that of international peers, senior, and some elite-level cohorts. Of note is that younger NZ players (U15) demonstrate greater physical, physiological, and kinematic demands than older players (U19).

In conclusion, the physical, physiological, and kinematic match characteristics of NZ secondary school-level competition can adequately prepare players for senior and higher-level rugby.

10.3 Limitations

This doctoral study was based on a number of delimitations and encountered several limitations of different kinds that should be considered when interpreting the information provided in this thesis. The following topical discussion outlines the limitations that could have had an impact on the process and therefore the outcome of the research.

General

This doctoral investigation focussed on NZ secondary school-level male youth RU players between the ages of thirteen and nineteen years. Therefore, the results of this study are not necessarily representative of other youth age cohorts, nationalities, or sexes. Due to the in-vivo practice-based nature of this research project in a team sport environment, certain contextual, as well as random situational factors were imposed on the research process. The necessity for repeated randomised quasi-experimental data collections, relating to the variety in design variables of the SSG (independent factors), limited the availability of whole teams and large subject groups, because of its intrusive and time-consuming character. As a consequence, convenience and availability sampling were used, which is known to be less optimal than fully randomised sampling.

Furthermore, because of availability and convenience sampling, and despite a large subject group overall, certain age categories were comparatively underrepresented. As a matter of course, the implications of the global 2020 COVID-19 pandemic impinged heavily on the sampling efforts performed up to date; schools and sport organisations ceased their activities and inevitably closed. These interruptions caused significant attrition in secondary school samples that had been established, as well as curtail the willingness to add additional constraints to training practice, during the immediate post-lockdown (one) period. As the repeated data collection spanned different seasons and school years, data of the same participants was collected on occasions and processed as individual and separate data points, in accordance with their age categorisation at that time.

The execution of the targeted perceptual, kinematic, and physiological data collection was made possible by collaboration through an external partnership with VX SPORT™. Exclusive wearable microsensor technology was made available during periods of the doctoral research project, without any interference on the research methodology. Availability of these devices was period-specific and subject to change. Consequently, and in spite of this indispensable partnership, measuring opportunities were limited to a certain degree.

The use of these microsensor devices, its reliability and accuracy were discussed in Chapter 3 (3.5 Measurements). Although 10 Hz GPS has been shown to be most adequate for capturing data in sport such as rugby, it is still wise to acknowledge that measurement inaccuracies and discrepancies will exist. The results obtained using this equipment are specific for these devices and should be carefully handled when comparing with microsensor devices of different makes and specifications.

Literature review

The limited number of studies included incurred certain limitations on the systematic review process. Firstly, a meta-analysis was not carried out, as the investigated studies' heterogeneity in design, methodology, and outcomes rendered this technique inapt. A greater inclusion-restriction of the identified evidence, based on RoB or quality rating, was omitted as it would have led to an excessively narrow scope. Consequently, the inferences were carefully drawn from a limited scientific basis of variable methodological quality. As outlined in the review, these inferences incurred some biases. The identified RoB and quality should therefore concomitantly form the scope through which the available evidence is interpreted, meaning that an important part of the preliminary and current evidence is not suited for wide extrapolation.

Despite the authors' conviction towards using the selected RoB and quality assessment, the quality scales were found lacking for full comprehensive evaluation of reporting methodology and non-differential bias of measurements. ROBINS – I furthermore entails the use of esoteric concepts and terminology. The extrapolation of which to non-clinical domains might be limited in its functionality. In spite its rigour and 'best fit', the authors acknowledge the need for contextually optimised RoB and quality assessment (i.e., team sport-specific) tools in future research. Furthermore, it needs to be recognised that recent evolutions in the field, although included in the narrative discussion, were not part of these systematic quality and RoB assessments.

In the systematic literature study, GPS sampling rates below 10 Hz were considered suboptimal, and therefore not fulfilling the validity and reliability requirements to confidently account for all intricacies of SSG play. The authors do recognise that in certain cases, for specific outcome measures, valid and reliable measurements could have been recorded with lower frequency GPS models. However, limited information about recording protocols does not allow for differentiation to that level.

In addition, the measurements captured by microsensor devices and outcome metrics reported (e.g., zones), were discussed as standard. However, these measures are far from standardised in sport science research. Within the scientific community, it is known that "researchers and practitioners have become comfortable using generic classifications… But it is still problematic". Moreover, this is seen as "a significant limitation in performance analysis" and remains unresolved (Dr. Timothy Hartwig, with permission). Therefore, mindfulness is required regarding the nature of the quantities or qualities evaluated in this study.

Survey

Despite extensive exposure through several electronic platforms, the total amount of completed surveys received was limited for its reach. A disproportionate return of survey responses from New Zealand, and in second instance Europe, means conclusions should only be generalised to those geographic cohorts. Certain limited strata might not fully represent their cohort, aside from geographical location, practitioners' experience, role, sex, target group, or playing level. The relative weight of these under-represented substrata should be considered when interpreting the results, for making inferences, and extrapolation. It is also important to note, that the survey provided participants with balanced teams (equal player numbers) SSG only, when selecting formats. The conclusions furthermore do not reflect the level of formal education of practitioners, as this was not surveyed.

Small-sided-games

Environmental conditions during SSG data collection were varied and could not be standardised. The conditions were nevertheless representative for a varied season in NZ (12-25 °C; 48-97% humidity, 1007-1026 mbar) and should therefore be interpreted as such. The practical implications of data collection within a secondary school context means cohorts may have been subject to peer influence, e.g., RPE collection. Furthermore, it is likely that not all individuals adhered strictly to the exact protocol (i.e., start/stop, passive recovery). Measurements are therefore close approximations of the ideal and representative for "real-world" practice. Age categories were not balanced in number of participants and absolute outcome values should consequently be taken primarily as a guideline.

Of note, because of the limitation in participant numbers and the nine specific SSG formats, data points for certain SSG formats within specific age cohorts were low. In addition, between-age group comparison was based on within-age cohort data and does not represent statistical significance. Further research within age categories using standardised SSG is needed to strengthen these conclusions. Apart from randomising allocation to conditions, maturation, position-specificity, and other potentially confounding elements such as psychological factors, as well as technical and tactical proficiency, were not accounted for in this study. Lastly, only balanced teams with equal player numbers (3v3, 5v5, 7v7) were investigated, meaning that any conclusions should be extrapolated to other format with reservations.

Matches

In terms of official matches, both the fifteen-and seven-a-side competition data incorporated relatively limited participants and matches. As a consequence, these outcomes are preliminary and should be strengthened by replication to scale these initial conclusions. The data is therefore also limited in terms of positional differences (forwards vs backs) and age differences (U19 vs U15), and not be representative of match-to-match variability across a whole season. Furter to that, opposition was not accounted for, other than pseudo-randomised convenience selection. The conclusions in this study apply to national-level NZ-based secondary school RU competition and any extrapolation should incur prudency Lastly, the practical implications of data collection with the aim of impinging as little as possible on normal match routines, within this open group school setting, has meant that participants may have been subject to peer influence, e.g., RPE collection.

10.4 Practical applications

This doctoral investigation aimed at improving the understanding of the application of SSG to youth male rugby union players in function of their match demands. To this aim, the different aspects of SSG implementation were studied in theory and practice, with a focus on the physical, physiological, and kinematic effects of SSG design variables. The body of evidence presented in this doctoral thesis allows us to formulate the following practical applications:

- Practitioners can use standardised SSG to prepare youth players for most demands of RU competition. Traditional endurance conditioning, HIIT, and contact training should supplement SSG to optimise players preparation for the most intense demands of the game.
- Practitioners should be aware that elemental SSG fall short of youth rugby 7s match demands, and thus need to be manipulated to modulate their intensity. Within this, practitioners should differentiate their training approach to accommodate the greater match demands in younger age groups. Of note, 7s format SSG can be used to prepare players for the "worst case scenario" peak demands of RU.
- Practitioners should adequately maximise the physiological stimulus by providing additional intrinsic and extrinsic constraints such as rule changes, physical tasks, motivating, and active coaching. Adequate time (≥2-3 minutes per bout) at high-intensity (90-95% HR_{MAX}) of multiple bouts aimed at upholding high-quality work, interspersed with adequate active recovery intervals should be pursued.
- Practitioners should prioritise player number and pitch size simultaneously when designing SSG, irrespective of age category, and before considering SSG bout structure. Maximising relative player area is most likely to maximise kinematic, physiological, and physical performance measures concurrently. As such, based on the current evidence presented herein, we would recommend using 3v3 on a large pitch (i.e., ½ full pitch; 70x50 m).
- Practitioners can use various SSG formats flexibly to suit their context and obtain similar performances; approximately 350 m^2 to 583 m^2 per player (5v5-L, 3v3-L) is recommended for maximising most kinematic, physiological, and physical outcomes. Relative playing area can be diminished to around 175 m^2 per player (5v5-M, 3v3-M) for several performance measures. However, maximising player numbers (7v7-L; 250 m^2 per player) is suboptimal for most performance measures. Practitioners can use the tables provided in this thesis to select the optimal format for targeting specific performance measures precisely.

- Practitioners targeting TD, RD, V_{AVG}, V_{MAX}, HR_{AVG}, HR_{MAX}, RPE, AL_{3D}, HIRD, HSRD, VHSRD, and $V_{Z4\text{-}Z5}$ (>80% V_{TOP}) with youth players can use 3v3-L (50x70 m) as a default format. Practitioners targeting sprint frequency and HIdec can default to 3v3-M (35x50 m). HIacc and time in HR_{Z5} (≥90% HR_{MAX}) can be optimally targeted with 3v3-S (25x35 m). Practitioners targeting recovery, return-to-play, or technical or tactical aspects can minimise the kinematic, physiological, and physical demands by using 7v7-S. Mindfulness towards differences between age cohorts is recommended. Practitioners of younger players (U14, U15) may use 3v3-M and 5v5-L to target V_{MAX}.
- Practitioners aiming to improve technical skills can select less demanding SSG formats with many interaction options (e.g., 7v7-S), with a focus on maximising skill execution quality, and evolve to more demanding formats with fewer interaction options and higher demands (e.g., 3v3-L), while maintaining the quality of skill execution.
- Practitioners should incorporate practically feasible intensity measurements such as RPE and HR into (SSG) training, to initiate youth into their use, and (self-)monitor training intensity. Furthermore, training progress should be tracked using performance measures or field-based testing such as the Bronco test (shuttle run). Subsequently, these measures can inform SSG training design, to suit training status and periodisation.
- Practitioners can apply various SSG formats, within meso- and microcycles, to effectively dose physiological and kinematic stimuli. In preseason, a basic evolution from low-to-moderate relative playing area SSG to high relative playing area formats may be applied. Additionally imposing physical demands using rule changes or creating player number imbalances, may assist in gradually building rugby-specific conditioning adequately. Especially when complemented by effective modulation and supplemented with specific training methods such as HIIT sessions. In season, practitioners may prioritise 7v7-S/M or 5v5-S/M without abundant constraints to schedule an ‘easy’ recovery session post-match, early in the week, or on “match day -1”, as a game-specific lower-impact stimulus. In contrast, a midweek 3v3-L SSG with multiple bouts and additional physical constraints/rules (e.g., down-ups), may help maintain or even improve competition readiness in a relatively safe manner.

- Practitioners can take players' absolute and relative 'benchmarks' from competitive games and optimal SSG formats, within and between cohorts (e.g., age groups, positions, primary/substitute/development player, first/second squad) to model within-season and cross-season progressions. For example, work capacity could be portrayed by RD at a given HR_{AVG}, measured in preseason. Following this benchmark, 3v3-L can progressively be implemented with increasing work bouts aimed at increasing RD at ≥90% HR_{AVG}. In competition, this may translate into a capacity for greater RD at lower $HR_{AVG.}$ These benchmarks can thereafter serve as a year-on-year stepwise improvement method and to compare with higher competition level benchmarks.
- Practitioner at lower and school level should be systematically educated on the full potential and practical application of SSG training in youth; e.g., the utility of multiple short-duration, high-quality, touch-rule work bouts and effective recovery intervals, as well as targeted and specialised tackle drills.
- Practitioners using SSG should aim at improving performance-determining measures such as RD, (repeated) sprint capacity, V_{MAX}, and HIacc, and can compare and contrast their observations to those of elite-level SSG play (Table 41).

10.5 Future research

This doctoral thesis has contributed evidence to the initial body of knowledge regarding GBT in rugby that provides novel insights into the application of SSG to youth RU players. The different studies contained in this doctoral research have indicated several areas for future research relating to this topic of SSG training and youth SSG^{RU}, in particular. The following aspects should inform future research and guide further investigation to pursue high-quality and practically relevant outcomes.

To strengthen the presented body of knowledge in this doctoral study, future research should replicate the results of this investigation. Researchers should investigate standardised SSG^{RU} formats progressively and cumulatively, following this focussed line of investigation. Primordially, the effects of (single) elemental design variables should be replicated within practically relevant age and competition cohorts (U14, U15, U16, U18, and others). A within-subject design would be an optimal approach. Player number relative to pitch size, and thus for exact SSG formats, should be compared, firstly.

Playing rules should be standardised and preferably non-contact. Confounding influences such as differences in population strata, rule discrepancies, or coach interference need to be avoided when these elements are not structurally under investigation. Full transparency is thereby essential for exact replication and to meaningfully compare with existing research. We recommend practically relevant player numbers and pitch sizes proportional to the full pitch, to be prioritised, as indicated in this doctoral study.

Following these investigations, the isolated effect of the other elemental design factors, age category and playing bouts, can be established, and replicated for standardised SSG formats. Between-cohort and bout comparison should incorporate statistical significance. The effects of playing rule modification should be a progression, after clearly establishing the influence of all elemental design variables within and between various specific cohorts.

The game characteristics of NZ-based secondary school fifteen and seven-a-side competition also warrant replication. These investigations should furthermore be replicated in various population strata and cohorts, nationally and internationally, to gain a global understanding of the similarities and differences within and between RU youth and senior cohorts (Figure 25).

In carrying out this future research, researchers should be mindful of avoiding bias in the research methodology; of note are bias due to measurement of outcomes, missing data, deviations from intended interventions, classification of interventions, and especially bias due to selection of participants and confounding. Future research regarding SSG and match demands would furthermore benefit greatly from the incorporation of relative measures such as relative speed zones, standardised definitions of performance measures such as "sprints", and the uniformisation of metrics such as heart rate and speed zones.

Regarding rugby-related SSG literature, future research would benefit from a systematic approach (e.g., PRISMA). Such reviews should furthermore incorporate and explicitly report RoB assessment, in addition to a methodologically appropriate form of quality assessment. To this aim, the development and validation of a purpose-designed sport science, field-based team sport, football, and rugby codes-specific study quality and RoB assessment tool, would optimise the appraisal of the existing body of knowledge within the field.

Future research with a focussed line of investigation should be replicated in male youth players, but also in female (youth) players, as well as across levels of play (Figure 1). As such, practically meaningful comparisons can be made, and pathway development can be optimised. Players' established strata- and cohort-specific absolute and relative competition and SSG 'benchmarks' can be used to model within-season and cross-season progressions. Reports of objective markers of longitudinal improvements in conditioning and kinematic outcomes are warranted in future research.

Lastly, despite the fact that relative performance measures have been shown to provide essential information in this doctoral study, nuancing within-cohort and between-position performances, absolute markers of SSG and match demands form a vital component for developmental progression (Figure 25). Performance-determining efforts such as V_{MAX}, HIacc, and sprint frequency (in function of repeated spring ability) are objective benchmarks for progression to the next higher level of competition. A pilot study from our research group on an elite-level international cohort indicates specific performance-determining measures form such benchmarks (ADDENDUM: An elite-level small-sided game pilot case study). In that regard, this doctoral work acts as a foundation for such a developmental pathway. Future research should aim to provide further progressive benchmarks across the performance-level spectrum for standardised SSG formats and competition matches.

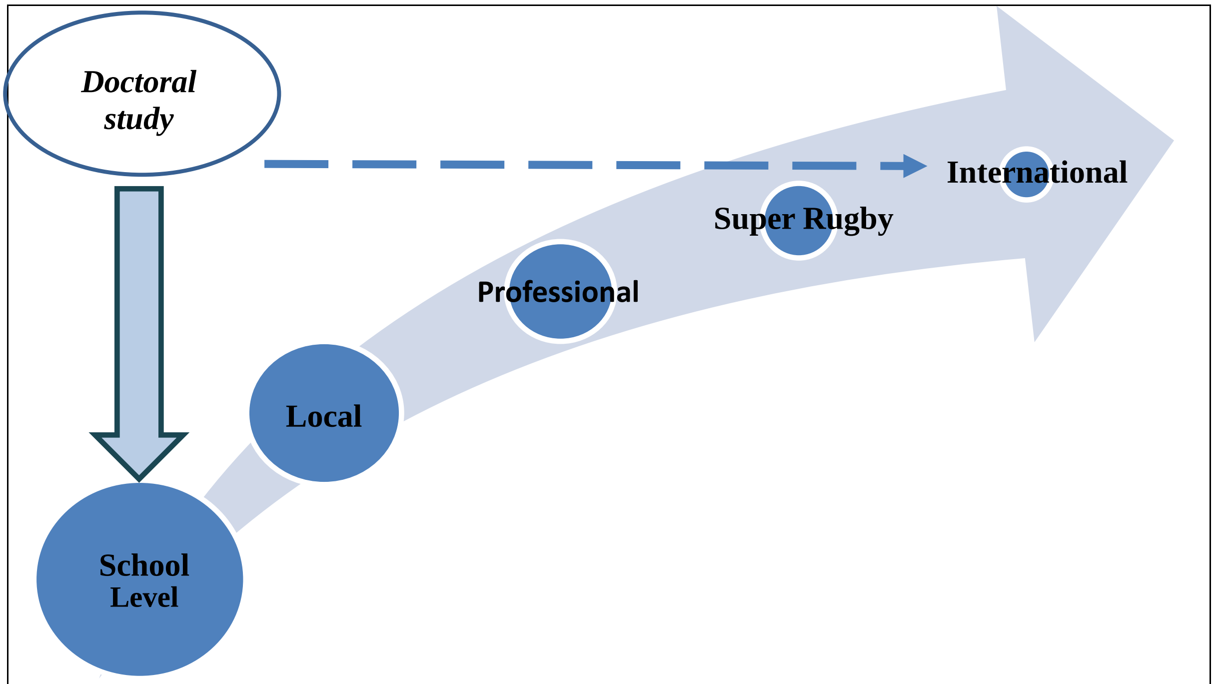

Figure 25 Current doctoral and future research within the levels of play in rugby union

ADDENDUM: An elite-level small-sided game pilot case study

Methods

A cross-sectional observational pilot case study was conducted in October 2020 on elite-level international RU players (n= 6; age= 24.7 ± 2.2; body weight= 110.7 ± 5.5 kg; height= 188.7 ± 6.7 cm; one prop, two outside backs, and three flankers). Kinematic data were collected using wearable VX SPORT™ microsensor technology (VXWR5Lb; 10 Hz GPS, Glonass, QZSS, SBAS, Galileo & BeiDou compatible; tri-axial 100 Hz accelerometer; 18 Hz magnetometer; 18 Hz gyroscope). Heart rate data was collected using Suunto HR monitors. Perceptual data was collected using the Borg scale (1-10). Data collection consisted of a coach-led training session including 3v3 touch on increasing pitch sizes (three four-minute bouts interspersed with two four-minute bouts of active recovery). Institutional ethical approval was obtained (HREC(Health)2019#16).

Pitch sizes:

- ⅛ (small (S)= 25x35 m / 875 m^2),
- ¼ (medium (M)= 35x50 m / 1750 m^2),
- ½ pitch (large (L)= 50x70 m / 3500 m^2)

Table 40 SSG training protocol elite-level RU players

PROTOCOL	DURANTION
General Warm Up Warm Up touch game on small field	
Game 1 - Small field 3v3	4 min
RECOVERY - 1 min off; 3 min of (Run 50 m:Jog 50 m x 3)	4 min
Game 2 - Medium field 3v3	4 min
RECOVERY - 1 min off; 3 min of (Run 50 m:Jog 50 m x 3)	4 min
Game 3 - Large field 3v3	4 min
Additional running intervals	

Results

Table 41 Small-sided game demands (3v3) in elite-level international RU players

	3v3				
	Bout1 (S) (4 mins) Mean ± SD	**Bout2 (M)** (4 mins) Mean ± SD	**Bout3 (L)** (4 mins) Mean ± SD	**Bout Avg** (4 mins) Mean ± SD	**SSG TOTAL** (20 mins) Mean ± SD
Total distance (TD) (m)	399.7 ± 36.7	455.5 ± 26.9	435.5 ± 43.9	430.2 ± 41.7	2197.8 ± 131.4
Relative distance (RD) ($m \cdot min^{-1}$)	100.7 ± 9.4	114.5 ± 6.9	109.5 ± 11.0	108.2 ± 10.5	110.3 ± 6.8
Average speed (V_{AVG}) ($km \cdot h^{-1}$)	6.0 ± 0.6	6.9 ± 0.4	6.6 ± 0.7	6.5 ± 0.6	6.6 ± 0.4
Maximal speed (V_{MAX}) ($km \cdot h^{-1}$)	21.9 ± 2.0	24.1 ± 3.4	26.0 ± 3.1	24.0 ± 3.2	27.5 ± 1.1
HIRD (m) (≥18 $km \cdot h^{-1}$)	15.3 ± 10.8	18.7 ± 17.0	39.0 ± 24.3	24.3 ± 20.2	305.2 ± 22.1
HSRD (m) (≥20 $km \cdot h^{-1}$)	6.7 ± 7.7	10.8 ± 10.8	29.5 ± 21.5	15.7 ± 17.1	177.7 ± 26.3
VHSRD (m) (≥25 $km \cdot h^{-1}$)	0.2 ± 0.4	2.8 ± 4.4	7.3 ± 7.1	3.4 ± 5.5	12.5 ± 7.9
Sprints	18.2 ± 2.9	20.2 ± 1.5	15.5 ± 2.1	17.9 ± 2.9	65.3 ± 5.6
HIacc (≥3 $m \cdot s^{-2}$)	16.7 ± 4.9	18.7 ± 6.0	14.3 ± 3.6	16.6 ± 5.0	62.7 ± 14.1
HIdec (≥3 $m \cdot s^{-2}$)	4.8 ± 2.6	4.7 ± 1.2	5.3 ± 1.6	4.9 ± 1.8	20.2 ± 4.3
Average heart rate ($beats \cdot min^{-1}$)	147.0 ± 43.9	154.6 ± 36.9	160.4 ± 22.8	154.5 ± 32.5	153.0 ± 32.2
Average heart rate (%HR_{MAX})	77.6 ± 23.2	81.7 ± 19.6	84.8 ± 12.1	81.6 ± 17.2	80.9 ± 17.1

Peak heart rate (beats·min^{-1})	154.0 ± 46.0	159.5 ± 43.1	170.0 ± 22.2	161.8 ± 34.8	169.8 ± 25.6
Peak heart rate (%HR_{MAX})	81.3 ± 24.4	84.2 ± 22.8	89.9 ± 11.8	85.5 ± 18.4	89.6 ± 13.6
ActivityLoad 3D rate (AL_{3D}) (AU)	5.0 ± 0.6	5.5 ± 0.7	5.1 ± 0.9	5.2 ± 0.7	5.0 ± 0.6
Body Impacts	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
RPE^{10}	6.0 ± 1.3	7.5 ± 0.5	8.4 ± 0.7	7.3 ± 1.3	8.4 ± 0.7

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APPENDICES

Appendix 1: Ethical approval

The University of Waikato
Private Bag 3105
Gate 1, Knighton Road
Hamilton, New Zealand

Human Research Ethics Committee
Julie Barbour
Telephone: +64 7 837 9336
Email:humanethics@waikato.ac.nz

THE UNIVERSITY OF
WAIKATO
Te Whare Wānanga o Waikato

27 March, 2019

Koen Wintershoven
By email: kw134@students.waikato.ac.nz (koenwintershoven@gmail.com)

Dear Koen,

HREC(Health)2019#15 : The use of small and large-sided games in rugby union – Survey

Thank you for submitting your amended application HREC(Health)2019#15 for ethical approval.

We are now pleased to provide formal approval for your anonymous survey of rugby coaches, regarding their use of and views towards small and large-sided games in rugby training. When the final version of the survey is complete, you are invited to submit your research instrument to the Ethics committee for our records.

We wish you all the best with your research.

Regards,

____

Julie Barbour PhD
Chairperson
University of Waikato Human Research Ethics Committee

The University of Waikato
Private Bag 3105
Gate 1, Knighton Road
Hamilton, New Zealand

Human Research Ethics Committee
Julie Barbour
Telephone: +64 7 837 9336
Email:humanethics@waikato.ac.nz

THE UNIVERSITY OF WAIKATO
Te Whare Wānanga o Waikato

27 March, 2019

Koen Wintershoven
By email: kw134@students.waikato.ac.nz (koenwintershoven@gmail.com)

Dear Koen,

HREC(Health)2019#16 : Application of small and large-sided games to rugby union: a match demands approach

Thank you for submitting your amended application HREC(Health)2019#16 for ethical approval.

We are now pleased to provide formal approval for your project including

1. Completion of a questionnaire covering age, sex, weight, height, and any new injuries that are sustained during the research,
2. Assessment of maximal running speed and heart rate,
3. Monitoring with GPS, and of heart rate, also perceived exertion and injury occurrence during game play. Participants will play at least one full rugby union match and/or three 4 minute bouts of small-sided games played with touch rules.

Please contact the committee by email (humanethics@waikato.ac.nz) if you wish to make changes to your project as it unfolds, quoting your application number with your future correspondence. Any minor changes or additions to the approved research activities can be handled outside the monthly application cycle.

We wish you all the best with your research.

Regards,

Julie Barbour PhD
Chairperson
University of Waikato Human Research Ethics Committee

Appendix 2: Player information sheet

Information Sheet for Participants

Title – Application of small and large-sided games to rugby union: A match demands approach.

Aim –To determine the demands of small and large- sided games in rugby union across all levels of play.

Background – Rugby is an important and highly demanding team sport that is played all over the world. Exceedingly more attention has gone to the impact of rugby on its players considering the increase in professionalism, growing player numbers, as well as performance and injuries. Training plays a crucial role in the development, preparation and safety of players. Small and larger-sided games are used in many sports to prepare players for the rigours of their sport. Although these training forms have been used in rugby for some time, the effects of various small and large-sided games have not yet been investigated properly in all ages and across playing levels. With this study we aim at improving the knowledge surrounding these training forms, to be implemented adequately in rugby union and benefit the development of rugby players across all levels.

Overview – Should you agree to participate, you will be asked to sign an informed consent form and complete a baseline questionnaire. Following this, a familiarisation session will be held during which measurements will be taken (including height and weight) and physical tests will be held (maximal speed and heart rate).

You will further be required to attend one or more training and match sessions at the school/club. During each session you will be allocated to one or more playing teams to execute three bouts of four-minute small-sided rugby games (touch rules) and participate in a full match (official rugby union rules).

During these activities you will be equipped with a portable GPS device and heart rate monitor which will record your performance (see image).

Each individual testing session should last no longer than 30 minutes. The full games will last the official length of a match (80 minutes).

What are the potential risks – The risks associated with participating in this study are no greater than those associated with performing normal rugby activities. If any harm does occur during study participation, the research team will offer immediate first aid and support you in accessing medical attention as required. If an injury does happen during testing, costs are likely to be covered – at least in part – by Accident Compensation Corporation.

What will happen to the information collected – The information collected will be used by the research team to write research reports, develop an optimised training tool for the use of small-sided games, give scientific presentations, and possibly help in educating students at the University of Waikato and the wider community. The information could be used in postgraduate student projects and thesis dissertations. Only the research team, their research associates, and students under their supervision will have direct access to the notes, documents, and recordings. At the end of the project, any personal information will be destroyed immediately except that, as required by the University's research policy, any raw data on which the results of the project depend will be retained in secure storage for five years, after which they will be destroyed. All data will be treated with the strictest confidentiality. No individual personal data will be reported, nor will you be named in the publications. Every effort will furthermore be made to disguise your identity. All data used for presentation purposes or in teaching will be de-identified (i.e., will not contain your personal information) to protect your identity and confidentiality. Notwithstanding, on request of coaching or teaching staff, specific players' data regarding the games under investigation, can be shared for educational or training purposes in aim of improving the players and the team. However, this is at your discretion and can be refused by contacting the primary investigator directly.

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Declaration to participants – If you take part in the study, you have the right to:
Ask any further questions about the study that occurs to you during your participation;

- A summary of findings from the study when it is concluded;
- Have a support person (family, whanau, and/or friend) present during your participation;
- Refuse to answer any particular question, and to withdraw from the study at any time;
- Withdraw any information you have provided up to two weeks after participating in the research activities by contacting the principal investigator.
- Receive an individualised report on request.

Who is responsible – If you have any questions about the project, please feel free to contact:

Koen Wintershoven, MSc, BEd. (Primary Investigator)
The University of Waikato, Adams Centre for High Performance
52 Miro Street, Mount Maunganui 3116
kw134@students.waikato.ac.nz

Dr. Daniel Travis McMaster (Primary Supervisor)
Research Fellow – Strength and Conditioning
The University of Waikato, Adams Centre for High Performance
52 Miro Street, Mount Maunganui 3116
daniel.mcmaster@waikato.ac.nz

Human Research Ethics Committee – This research project has been approved by the Human Research Ethics Committee (Health) of the University of Waikato under *HREC(Health)#2019-16.*

Any questions about the ethical conduct of this research may be addressed to the Secretary of the Committee, email humanethics@waikato.ac.nz, postal address, University of Waikato, Te Whare Wananga o Waikato, Private Bag 3105, Hamilton 3240.

THE UNIVERSITY OF WAIKATO
Te Whare Wānanga o Waikato

Information Summary for Participants

Title – Application of small and large-sided games (SSGs) to rugby union: A match demands approach.

Aim – Determine the demands of small and large- sided games in rugby union across all levels of play.

Background – SSGs are used in rugby and other sports to prepare players for competition. However, knowledge of various SSGs in rugby is limited. Therefore, investigation of SSGs in rugby will lead to optimised training, thus the development of rugby players across all levels.

Overview – Should you agree to participate, you will:

- Sign an informed consent form,
- Complete a baseline questionnaire,
- Get a familiarisation session with the testing gear whilst undergoing maximal speed and heart rate tests,
- Take part in SSGs and match play.

Potential risks – No foreseeable risks other than those inherent to rugby.

What will happen to the information collected – The information collected will be used for:

- Research reports,
- Development of an optimised training tool,
- Give scientific presentations,
- Education purposes.

All information will be treated with strict confidentiality. No personal information will be disclosed. Only the research team has access to it. At the end of the project the information can be safely kept for a maximum of five years, after which it will be destroyed.

Declaration to participants – If you take part in the study, you have the right to:

- Ask questions,
- Information about the study outcome,
- Have a support person present,
- Refuse to answer any question, and to withdraw from the study,
- Withdraw any information up to two weeks after participating.

Who is responsible – If you have any questions about the project, please feel free to contact:

Koen Wintershoven, MSc, BEd. (Primary Investigator)
The University of Waikato - Adams Centre for High Performance
52 Miro Street, Mount Maunganui 3116
kw134@students.waikato.ac.nz

Human Research Ethics Committee – This research project has been approved by the Human Research Ethics Committee (Health) of the University of Waikato under *HREC(Health)#2019-1*

THE UNIVERSITY OF WAIKATO
Te Whare Wānanga o Waikato

Appendix 3: Informed consent form

Consent Form for Participants

Title – Application of small and large-sided games to rugby union: a match demands approach.

I have read the Participant Information Sheet for this study and have had the details of the study explained to me. My questions about the study have been answered to my satisfaction, and I understand that I may ask further questions at any time.

I also understand that:

- *Participation in this study is voluntary.*
- *I am free to withdraw from the study at any time or to decline to answer any particular questions.*
- *I can withdraw any information I have provided up to two weeks after participating in the research activities by contacting the principal investigator.*
- *Any data or answers will remain confidential regarding my identity through a coding system.*
- *The data might be published, so every effort will be made to ensure confidentiality and anonymity. However, anonymity cannot be guaranteed.*
- *The data might be shared on request with coaching or teaching staff for educational or training purposes, unless requested otherwise by the participant.*

I agree to provide information to the researchers under the conditions of confidentiality set out on the Participant Information Sheet.

Consent to Participate

I agree to the participation in this study under the conditions set out in the Participant Information Sheet.

	Participant:	**Legal guardian (mandatory for under 16):**
Signature:	__________________________	__________________________
Name:	__________________________	__________________________
Date:	__________________________	__________________________

		Researcher:
Signature:	__________________________	__________________________
Name:	__________________________	__________________________
Date:	__________________________	__________________________

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Appendix 4: Player form

GIVEN NAME (capital letters)	
LAST NAME (capital letters)	
DATE OF BIRTH (dd/mm/yyyy)	**----- / ----- / -----**
TEAM /SCHOOL/ ACADEMY (capital letters)	
COMPETITION / PLAYING LEVEL (circle)	**SCHOOL – LOCAL – NATIONAL – SUPER RUGBY - INTERNATIONAL**
NORMAL PLAYING POSITION (circle)	**FORWARD – BACK** **1 - 2 - 3 – 4 – 5 - 6 – 7 – 8 – 9 – 10 – 11 – 12 – 13 – 14 - 15**
Height (cm)	
Body weight (.x Kg)	
Max. heart rate (bpm)	
Max. running speed ($Km.h^{-1}$)	
Remarks	

Appendix 5: Testing form

TEAM NAME / NUMBER:
DATE & START + END TIME: 15/07/2020 – Start:_____ End:_____
SSG FORMAT (circle) 3v3 or 5v5 or 7v7 and FIELD SIZE: S or M or L

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Athlete Name/ Number	BOUT 1		BOUT 2		BOUT 3	
	RPE (6-20)	Injury (Y/N)	RPE (6-20)	Injury (Y/N)	RPE (6-20)	Injury (Y/N)

Borg Rating of Perceived Exertion

6 No exertion at all
7
Extremely light
8
9 Very light
10
11 Light
12
13 Somewhat hard
14
15 Hard (heavy)
16
17 Very hard
18
19 Extremely hard
20 Maximal exertion

If sustained an injury, please specify athlete and injury type:

304

Appendix 6: Risk of bias assessment

Rater 1 - The Risk Of Bias In Non-randomized Studies – of Interventions (ROBINS-I) assessment tool

(version for cohort-type studies)

Version 19 September 2016 ROBINS-I tool (Stage I): At protocol stage

Specify the review question

Participants	MALE RUGBY UNION PLAYERS
Experimental intervention	APPLICATION OF SMALL-SIDED GAMES
Comparator	TRADITIONAL RUGBY TRAINING
Outcomes	TRAINING RESPONSES (CHRONIC AND ACUTE) *[“effects on physiological, kinematic, physical, technical, tactical variables”]*

List the confounding domains relevant to all or most studies

(A confounding domain is a pre-intervention prognostic factor that predicts whether an individual receives one or the other intervention of interest, and is predictive of the outcome of the intervention)

- Coach’s subjective assessment of players’ overall performance level → channelling bias, allocation bias
- Overlapping roles (investigator- coach) (= Conflict of Interest) → inclusive bias (due to convenience sampling), performance bias, reporting bias, observer bias
- Players’ Lifestyle factors (sleep, fatigue, stress, smoking, diet, activity levels)
- Players’ characteristics (age, body composition, baseline fitness level)
- Talent (inherent skill level)
- Playing position (e.g., Backs vs. forwards)

IF NOT EXCPLICITELY CONTROLED FOR THESE FORESEEN RISKS OF BIAS IN INDIVIDUAL STUDIES = risk of bias will be quoted as SERIOUS (because no randomisation)

List co-interventions that could be different between intervention groups and that could impact on outcomes

TRAINING STRUCTURE

- Non-conditioning training?
- Timing of training standardized (on weekly and daily level)?
- Timing within training standardized (groups receive condition at the same time within training?)
- Training content (activities) standardized (warm-up effect, fatigue effect)?

PRE- TRAINING PREPARATION & NUTRITION

Club meals, caffeine, massage, foam rolling,… needs to be equal for groups. IF any.

ROBINS-I tool (Stage II): For each study: A skilled-based conditioning games approach to metabolic conditioning for elite rugby football players (Gamble (2004))

Specify a target randomized trial specific to the study

Design	Individually randomized / Cluster randomized / Matched (e.g. cross-over)
Participants	Elite-level rugby union players
Experimental intervention	Metabolic conditioning through SSGs
Comparator	All other rugby training (-SSGs) → "Traditional conditioning" not done in this team, and furthermore research Q is; do SSGs condition?

Is your aim for this study…?

- ☐ to assess the effect of *assignment to* intervention
- ☐ to assess the effect of *starting and adhering to* intervention

Specify the outcome

Specify which outcome is being assessed for risk of bias (typically from among those earmarked for the Summary of Findings table). Specify whether this is a proposed benefit or harm of intervention.

Benefits: HR (Lower $\%HR_{MAX}$ at test end stage, better HR recovery score)

Specify the numerical result being assessed

In case of multiple alternative analyses being presented, specify the numeric result (e.g. RR = 1.52 (95% CI 0.83 to 2.77) and/or a reference (e.g. to a table, figure or paragraph) that uniquely defines the result being assessed.

$\rho<.05$ for $\%HR_{MAX}$ and HRrecovery

Preliminary consideration of confounders

Complete a row for each important confounding domain (i) listed in the review protocol; and (ii) relevant to the setting of this particular study, or which the study authors identified as potentially important.

"Important" confounding domains are those for which, in the context of this study, adjustment is expected to lead to a clinically important change in the estimated effect of the intervention. "Validity" refers to whether the confounding variable or variables fully measure the domain, while "reliability" refers to the precision of the measurement (more measurement error means less reliability).

(i) Confounding domains listed in the review protocol				
Confounding domain	Measured variable(s)	Is there evidence that controlling for this variable was unnecessary?*	Is the confounding domain measured validly and reliably by this variable (or these variables)?	OPTIONAL: Is failure to adjust for this variable (alone) expected to favour the experimental intervention or the comparator?
Coach's subjective assessment of players' overall performance level → channeling bias, allocation bias	Randomisation Or identical exposure per player to SSGs	No	Yes / No / No information	Favour experimental / Favour comparator / No information
Overlapping roles (investigator- coach) (= Conflict of Interest) → inclusive bias (due to convenience sampling), observer bias, performance bias, reporting bias	Concealment of allocation to SSGs, Randomisation, Identical exposure per player to SSGs, Or statement of neutrality	No	Yes / No / No information	Favour experimental / Favour comparator / No information
Players' Lifestyle factors (sleep, fatigue, stress, smoking, diet, activity levels)	Randomisation Or equal exposure per player to SSGs	No	Yes / No / No information	Favour experimental / Favour comparator / No information
Players' characteristics (age, body composition, baseline fitness level)	Clear measurement of these characteristics at baseline, Randomisation, Or equal exposure per player to SSGs	No	Yes / No / No information	Favour experimental / Favour comparator / No information

Talent (inherent skill level)	Randomisation, Objective skill test, Or equal exposure per player to SSGs	Improvements in (group) outcome, irrespective of whom played what and when..?	Yes / No / No information	Favour experimental / Favour comparator / No information
Playing position (e.g. Backs vs. forwards)	Randomisation or Matched and cross-over design	Yes. Idem as above?	Yes / No / No information	Favour experimental / Favour comparator / No information

(ii) Additional confounding domains relevant to the setting of this particular study, or which the study authors identified as important				
Confounding domain	Measured variable(s)	Is there evidence that controlling for this variable was unnecessary?*	Is the confounding domain measured validly and reliably by this variable (or these variables)?	OPTIONAL: Is failure to adjust for this variable (alone) expected to favour the experimental intervention or the comparator?
			Yes / No / No information	Favour experimental / Favour comparator / No information

* In the context of a particular study, variables can be demonstrated not to be confounders and so not included in the analysis: (a) if they are not predictive of the outcome; (b) if they are not predictive of intervention; or (c) because adjustment makes no or minimal difference to the estimated effect of the primary parameter. Note that “no statistically significant association” is not the same as “not predictive”.

Preliminary consideration of co-interventions

Complete a row for each important co-intervention (i) listed in the review protocol; and (ii) relevant to the setting of this particular study, or which the study authors identified as important.

"Important" co-interventions are those for which, in the context of this study, adjustment is expected to lead to a clinically important change in the estimated effect of the intervention.

(i) Co-interventions listed in the review protocol		
Co-intervention	Is there evidence that controlling for this co-intervention was unnecessary (e.g. because it was not administered)?	Is presence of this co-intervention likely to favour outcomes in the experimental intervention or the comparator
TRAINING STRUCTURE • Non-conditioning training • Timing of conditioning training standardized (on weekly and daily level)? • Timing within training standardized (groups receive condition at the same time within training?) • Training content (activities) standardized (warm-up effect, fatigue effect)?	No	Favour experimental / Favour comparator / No information
PRE- TRAINING PREPARATION & NUTRITION Club meals, caffeine, massage, foam rolling,… needs to be equal for groups. IF any.	No	Favour experimental / Favour comparator / No information

(ii) Additional co-interventions relevant to the setting of this particular study, or which the study authors identified as important		
Co-intervention	Is there evidence that controlling for this co-intervention was unnecessary (e.g. because it was not administered)?	Is presence of this co-intervention likely to favour outcomes in the experimental intervention or the comparator
		Favour experimental / Favour comparator / No information

Risk of bias assessment

Responses underlined in green are potential markers for low risk of bias, and responses in red are potential markers for a risk of bias. Where questions relate only to sign posts to other questions, no formatting is used.

Signalling questions	Description	Response options
Bias due to confounding		
1.1 Is there potential for confounding of the effect of intervention in this study? **If N/PN to 1.1:** the study can be considered to be at low risk of bias due to confounding and no further signalling questions need be considered	• Coach's subjective assessment of players' overall performance level might lead to less/more exposure • Overlapping roles (investigator- coach) (= Conflict of Interest) • Players' Lifestyle factors (sleep, fatigue, stress, smoking, diet, activity levels) • Players' characteristics (age, body composition, baseline fitness level) • Talent (inherent skill level) • Playing position (e.g. Backs vs. forwards)	Y / PY / PN / N
If Y/PY to 1.1: determine whether there is a need to assess time-varying confounding:		
1.2. Was the analysis based on splitting participants' follow up time according to intervention received? **If N/PN**, answer questions relating to baseline confounding (1.4 to 1.6) **If Y/PY**, go to question 1.3.		NA / Y / PY / PN / N / NI
1.3. Were intervention discontinuations or switches likely to be related to factors that are prognostic for the outcome? **If N/PN**, answer questions relating to baseline confounding (1.4 to 1.6) **If Y/PY**, answer questions relating to both baseline and time-varying confounding (1.7 and 1.8)		NA / Y / PY / PN / N / NI

Questions relating to baseline confounding only		
1.4. Did the authors use an appropriate analysis method that controlled for all the important confounding domains?	Need for concealment of allocation, randomisation, and no conflict of interests.	NA / Y / PY / PN / N / NI

1.5. **If Y/PY to 1.4**: Were confounding domains that were controlled for measured validly and reliably by the variables available in this study?		NA / Y / PY / PN / N / NI
1.6. Did the authors control for any post-intervention variables that could have been affected by the intervention?		NA / Y / PY / PN / N / NI
Questions relating to baseline and time-varying confounding		
1.7. Did the authors use an appropriate analysis method that controlled for all the important confounding domains and for time-varying confounding?	Need for concealment of allocation, randomisation, and no conflict of interests.	NA / Y / PY / PN / N / NI
1.8. **If Y/PY to 1.7**: Were confounding domains that were controlled for measured validly and reliably by the variables available in this study?		NA / Y / PY / PN / N / NI
Risk of bias judgement		Low / Moderate / Serious / Critical / NI
Optional: What is the predicted direction of bias due to confounding?		Favours experimental / Favours comparator / Unpredictable

Bias in selection of participants into the study		
2.1. Was selection of participants into the study (or into the analysis) based on participant characteristics observed after the start of intervention? **If N/PN to 2.1:** go to 2.4	Available club players = Convenience sampling.	Y / PY / PN / N / NI
2.2. **If Y/PY to 2.1**: Were the post-intervention variables that influenced selection likely to be associated with intervention?		NA / Y / PY / PN / N / NI
2.3 **If Y/PY to 2.2**: Were the post-intervention variables that influenced selection likely to be influenced by the outcome or a cause of the outcome?		NA / Y / PY / PN / N / NI
2.4. Do start of follow-up and start of intervention coincide for most participants?		Y / PY / PN / N / NI
2.5. **If Y/PY to 2.2 and 2.3, or N/PN to 2.4**: Were adjustment techniques used that are likely to correct for the presence of selection biases?		NA / Y / PY / PN / N / NI
Risk of bias judgement	What about the fact that convenience sampling was used? Not necessarily the "average" professional rugby player.	Low / Moderate / Serious / Critical / NI
Optional: What is the predicted direction of bias due to selection of participants into the study?	Very fit professional players; diminishing returns → little or no significant improvements to be expected.	Favours experimental / Favours comparator / Towards null /Away from null / Unpredictable

Bias in classification of interventions		
3.1 Were intervention groups clearly defined?	Only one group. Clear rationale given. Own baseline measures used as control.	Y / PY / PN / N / NI
3.2 Was the information used to define intervention groups recorded at the start of the intervention?	Only one group. Group characteristics clearly stated. Convenience sampling.	Y / PY / PN / N / NI
3.3 Could classification of intervention status have been affected by knowledge of the outcome or risk of the outcome?	All players exposed to condition (SSGs), considering stakes in professional rugby. However, researcher-coach prior knowledge, empirically, and from literature. Large part of group had previous experience with SSG conditioning. No control group → recall bias (players), expectation bias (players, coach-researcher)?	Y / PY / PN / N / NI
Risk of bias judgement		Low / Moderate / Serious / Critical / NI
Optional: What is the predicted direction of bias due to classification of interventions?		Favours experimental / Favours comparator / Towards null /Away from null / Unpredictable
Bias due to deviations from intended interventions		
If your aim for this study is to assess the effect of assignment to intervention, answer questions 4.1 and 4.2		
4.1. Were there deviations from the intended intervention beyond what would be expected in usual practice?		Y / PY / PN / N / NI
4.2. **If Y/PY to 4.1**: Were these deviations from intended intervention unbalanced between groups *and* likely to have affected the outcome?		NA / Y / PY / PN / N / NI
If your aim for this study is to assess the effect of starting and adhering to intervention, answer questions 4.3 to 4.6		
4.3. Were important co-interventions balanced across intervention groups?	Only one group. All players were exposed to all training. Pre-training preparation and nutrition was not mentioned, but likely to have been kept as usual.	Y / PY / PN / N / NI
4.4. Was the intervention implemented successfully for most participants?		Y / PY / PN / N / NI
4.5. Did study participants adhere to the assigned intervention regimen?	Only one injury reported. No illnesses or other factors reported.	Y / PY / PN / N / NI
4.6. **If N/PN to 4.3, 4.4 or 4.5**: Was an appropriate analysis used to estimate the effect of starting and adhering to the intervention?		NA / Y / PY / PN / N / NI
Risk of bias judgement		Low / Moderate / Serious / Critical / NI

Optional: What is the predicted direction of bias due to deviations from the intended interventions?		Favours experimental / Favours comparator / Towards null /Away from null / Unpredictable

Bias due to missing data		
5.1 Were outcome data available for all, or nearly all, participants?	Only one exclusion (long-term injury) reported. Some data was only reported graphically (e.g. group mean HR test at start of intervention). No clear reason to assume more missing data. However, tactical training (co-intervention) was mentioned, but nor specified.	Y / PY / PN / N / NI
5.2 Were participants excluded due to missing data on intervention status?		Y / PY / PN / N / NI
5.3 Were participants excluded due to missing data on other variables needed for the analysis?		Y / PY / PN / N / NI
5.4 **If PN/N to 5.1, or Y/PY to 5.2 or 5.3**: Are the proportion of participants and reasons for missing data similar across interventions?		NA / Y / PY / PN / N / NI
5.5 **If PN/N to 5.1, or Y/PY to 5.2 or 5.3**: Is there evidence that results were robust to the presence of missing data?		NA / Y / PY / PN / N / NI
Risk of bias judgement		Low / Moderate / Serious / Critical / NI
Optional: What is the predicted direction of bias due to missing data?		Favours experimental / Favours comparator / Towards null /Away from null / Unpredictable

Bias in measurement of outcomes		
6.1 Could the outcome measure have been influenced by knowledge of the intervention received?	Some influencing of HR can occur. But highly unlikely with professional athletes who are used to SSGs. Furthermore, rationale provided for nullification of psychological arousal of HR due to high intensity.	Y / PY / PN / N / NI
6.2 Were outcome assessors aware of the intervention received by study participants?	Coach-researcher	Y / PY / PN / N / NI
6.3 Were the methods of outcome assessment comparable across intervention groups?	Only one group. Same measurement each week.	Y / PY / PN / N / NI

6.4 Were any systematic errors in measurement of the outcome related to intervention received?	$HR_{recovery}$ (fitness test) is dependent on heart rate reserve (HRR), depends on resting HR. HR_{rest} was updated every training session, but measured during pre-training meeting ≠ true HR_{rest} (likely inaccurate, i.e. higher)	Y / PY / PN / N / NI
Risk of bias judgement	6.2. Influencing intervention group towards positive outcome was inherent to experimental set-up. 6.4. If resting HR was overestimated, HRR was underestimated. Therefore, fitness test recovery scores would be overestimated (larger proportion (%) of HRR). Nevertheless, also significant improvements (decline) in $\%HR_{MAX}$.	Low / Moderate / Serious / Critical / NI
Optional: What is the predicted direction of bias due to measurement of outcomes?		Favours experimental / Favours comparator / Towards null /Away from null / Unpredictable

Bias in selection of the reported result		
Is the reported effect estimate likely to be selected, on the basis of the results, from... 7.1. ... multiple outcome *measurements* within the outcome domain?	Periodical video-analysis not reported, but would have no influence on HR outcome.	Y / PY / PN / N / NI
7.2 ... multiple *analyses* of the intervention-outcome relationship?		Y / PY / PN / N / NI
7.3 ... different *subgroups*?	Two subgroups (new vs. existing). Both reported.	Y / PY / PN / N / NI
Risk of bias judgement		Low / Moderate / Serious / Critical / NI
Optional: What is the predicted direction of bias due to selection of the reported result?		Favours experimental / Favours comparator / Towards null /Away from null / Unpredictable

Overall bias		
Risk of bias judgement		Low / Moderate / Serious / Critical / NI
Optional: What is the overall predicted direction of bias for this outcome?		Favours experimental / Favours comparator / Towards null /Away from null / Unpredictable

ROBINS-I tool (Stage II): For each study: Influence of different small-sided games on physical and physiological demands in rugby union players (Kennett, Kempton, and Coutts (2012))

Specify a target randomized trial specific to the study

Design	Individually randomized / Cluster randomized / Matched (e.g. cross-over)
Participants	Semi-professional rugby union players
Experimental intervention	Influence of prescriptive design variables (player number and field size) on training responses in rugby SSGs
Comparator	4 vs. 4, 6 vs. 6, 8 vs. 8, and small pitch vs. large pitch

Is your aim for this study…?

- ☐ to assess the effect of *assignment to* intervention
- ☐ to assess the effect of *starting and adhering to* intervention

315

Specify the outcome

Specify which outcome is being assessed for risk of bias (typically from among those earmarked for the Summary of Findings table). Specify whether this is a proposed benefit or harm of intervention.

Benefits: physiological, perceptual, kinematical outcome

Specify the numerical result being assessed

In case of multiple alternative analyses being presented, specify the numeric result (e.g. RR = 1.52 (95% CI 0.83 to 2.77) and/or a reference (e.g. to a table, figure or paragraph) that uniquely defines the result being assessed.

$\rho < .05$ for %HR_{MAX}, Blood lactate, RPE, GPS

Preliminary consideration of confounders

Complete a row for each important confounding domain (i) listed in the review protocol; and (ii) relevant to the setting of this particular study, or which the study authors identified as potentially important.

"Important" confounding domains are those for which, in the context of this study, adjustment is expected to lead to a clinically important change in the estimated effect of the intervention. "Validity" refers to whether the confounding variable or variables fully measure the domain, while "reliability" refers to the precision of the measurement (more measurement error means less reliability).

(i) Confounding domains listed in the review protocol				
Confounding domain	Measured variable(s)	Is there evidence that controlling for this variable was unnecessary?*	Is the confounding domain measured validly and reliably by this variable (or these variables)?	OPTIONAL: Is failure to adjust for this variable (alone) expected to favour the experimental intervention or the comparator?
Coach's subjective assessment of players' overall performance level → channeling bias, allocation bias	Randomisation Or identical exposure per player to SSGs	Yes, no direct evidence of influence on experimental design from coaching staff	Yes / No / No information	Favour experimental / Favour comparator / No information
Overlapping roles (investigator- coach) (= Conflict of Interest) → inclusive bias (due to convenience sampling), observer bias, performance bias, reporting bias	Concealment of allocation to SSGs, Randomisation, Identical exposure per player to SSGs, Or statement of neutrality	Yes, no evidence of overlapping roles.	Yes / No / No information	Favour experimental / Favour comparator / No information
Players' Lifestyle factors (sleep, fatigue, stress, smoking, diet, activity levels)	Randomisation Or equal exposure per player to SSGs	Yes, clearly stated standardisation of training time, food and fluid intake.	Yes / No / No information	Favour experimental / Favour comparator / No information
Players' characteristics (age, body composition, baseline fitness level)	Clear measurement of these characteristics at baseline, Randomisation, Matching, Or equal exposure per player to SSGs	Yes, clearly stated objective skill and fitness matching.	Yes / No / No information	Favour experimental / Favour comparator / No information

Talent (inherent skill level)	Randomisation, Objective skill test, Or equal exposure per player to SSGs	Yes, clearly stated objective skill and fitness matching.	Yes / No / No information	Favour experimental / Favour comparator / No information
Playing position (e.g. Backs vs. forwards)	Randomisation or Matched and cross-over design	Yes. Idem as above?	Yes / No / No information	Favour experimental / Favour comparator / No information

(ii) Additional confounding domains relevant to the setting of this particular study, or which the study authors identified as important				
Confounding domain	Measured variable(s)	Is there evidence that controlling for this variable was unnecessary?*	Is the confounding domain measured validly and reliably by this variable (or these variables)?	OPTIONAL: Is failure to adjust for this variable (alone) expected to favour the experimental intervention or the comparator?
			Yes / No / No information	Favour experimental / Favour comparator / No information

* In the context of a particular study, variables can be demonstrated not to be confounders and so not included in the analysis: (a) if they are not predictive of the outcome; (b) if they are not predictive of intervention; or (c) because adjustment makes no or minimal difference to the estimated effect of the primary parameter. Note that “no statistically significant association” is not the same as “not predictive”.

Preliminary consideration of co-interventions

Complete a row for each important co-intervention (i) listed in the review protocol; and (ii) relevant to the setting of this particular study, or which the study authors identified as important.

"Important" co-interventions are those for which, in the context of this study, adjustment is expected to lead to a clinically important change in the estimated effect of the intervention.

(i) Co-interventions listed in the review protocol		
Co-intervention	Is there evidence that controlling for this co-intervention was unnecessary (e.g. because it was not administered)?	Is presence of this co-intervention likely to favour outcomes in the experimental intervention or the comparator
TRAINING STRUCTURE • Non-conditioning training • Timing of conditioning training standardized (on weekly and daily level)? • Timing within training standardized (groups receive condition at the same time within training?) • Training content (activities) standardized (warm-up effect, fatigue effect)?	Yes, training timing, food and fluid intake, coach encouragement, skill and fitness, refereeing, rules, and team composition were all accounted for through randomisation. It is reasonable to assume that the within-training timing of SSGs and other content was too.	Favour experimental / Favour comparator / No information
PRE- TRAINING PREPARATION & NUTRITION Club meals, caffeine, massage, foam rolling,… needs to be equal for groups. IF any.	Yes, see above.	Favour experimental / Favour comparator / No information
		Favour experimental / Favour comparator / No information
		Favour experimental / Favour comparator / No information

(ii) Additional co-interventions relevant to the setting of this particular study, or which the study authors identified as important

Co-intervention	Is there evidence that controlling for this co-intervention was unnecessary (e.g. because it was not administered)?	Is presence of this co-intervention likely to favour outcomes in the experimental intervention or the comparator

Risk of bias assessment

Responses underlined in green are potential markers for low risk of bias, and responses in red are potential markers for a risk of bias. Where questions relate only to sign posts to other questions, no formatting is used.

Signalling questions	Description	Response options
Bias due to confounding		
1.1 Is there potential for confounding of the effect of intervention in this study? **If N/PN to 1.1:** the study can be considered to be at low risk of bias due to confounding and no further signalling questions need be considered		Y / PY / PN / N
If Y/PY to 1.1: determine whether there is a need to assess time-varying confounding:		
1.2. Was the analysis based on splitting participants' follow up time according to intervention received? **If N/PN**, answer questions relating to baseline confounding (1.4 to 1.6) **If Y/PY**, go to question 1.3.		NA / Y / PY / PN / N / NI
1.3. Were intervention discontinuations or switches likely to be related to factors that are prognostic for the outcome? **If N/PN**, answer questions relating to baseline confounding (1.4 to 1.6) **If Y/PY**, answer questions relating to both baseline and time-varying confounding (1.7 and 1.8)		NA / Y / PY / PN / N / NI
Questions relating to baseline confounding only		
1.4. Did the authors use an appropriate analysis method that controlled for all the important confounding domains?		NA / Y / PY / PN / N / NI
1.5. **If Y/PY to 1.4**: Were confounding domains that were controlled for measured validly and reliably by the variables available in this study?		NA / Y / PY / PN / N / NI
1.6. Did the authors control for any post-intervention variables that could have been affected by the intervention?		NA / Y / PY / PN / N / NI

Questions relating to baseline and time-varying confounding		
1.7. Did the authors use an appropriate analysis method that controlled for all the important confounding domains and for time-varying confounding?		NA / Y / PY / PN / N / NI
1.8. **If Y/PY to 1.7**: Were confounding domains that were controlled for measured validly and reliably by the variables available in this study?		NA / Y / PY / PN / N / NI
Risk of bias judgement		Low / Moderate / Serious / Critical / NI
Optional: What is the predicted direction of bias due to confounding?		Favours experimental / Favours comparator / Unpredictable

Bias in selection of participants into the study		
2.1. Was selection of participants into the study (or into the analysis) based on participant characteristics observed after the start of intervention? **If N/PN to 2.1:** go to 2.4	Players matched for skill and fitness, and randomised into teams, per SSG format.	Y / PY / PN / N / NI
2.2. **If Y/PY to 2.1**: Were the post-intervention variables that influenced selection likely to be associated with intervention?		NA / Y / PY / PN / N / NI
2.3 **If Y/PY to 2.2**: Were the post-intervention variables that influenced selection likely to be influenced by the outcome or a cause of the outcome?		NA / Y / PY / PN / N / NI
2.4. Do start of follow-up and start of intervention coincide for most participants?	No follow up	Y / PY / PN / N / NI
2.5. **If Y/PY to 2.2 and 2.3, or N/PN to 2.4**: Were adjustment techniques used that are likely to correct for the presence of selection biases?		NA / Y / PY / PN / N / NI
Risk of bias judgement		Low / Moderate / Serious / Critical / NI
Optional: What is the predicted direction of bias due to selection of participants into the study?		Favours experimental / Favours comparator / Towards null /Away from null / Unpredictable

Bias in classification of interventions		
3.1 Were intervention groups clearly defined?	Only one intervention group, i.e. rugby team, from which players were allocated into opposing teams per specific SSG. The different SSG formats were defined using player number and pitch sizes.	Y / PY / PN / N / NI

3.2 Was the information used to define intervention groups recorded at the start of the intervention?		Y / PY / PN / N / NI
3.3 Could classification of intervention status have been affected by knowledge of the outcome or risk of the outcome?		Y / PY / PN / N / NI
Risk of bias judgement		Low / Moderate / Serious / Critical / NI
Optional: What is the predicted direction of bias due to classification of interventions?		Favours experimental / Favours comparator / Towards null /Away from null / Unpredictable

Bias due to deviations from intended interventions		
If your aim for this study is to assess the effect of assignment to intervention, answer questions 4.1 and 4.2		
4.1. Were there deviations from the intended intervention beyond what would be expected in usual practice?		Y / PY / PN / N / NI
4.2. **If Y/PY to 4.1**: Were these deviations from intended intervention unbalanced between groups *and* likely to have affected the outcome?		NA / Y / PY / PN / N / NI
If your aim for this study is to assess the effect of starting and adhering to intervention, answer questions 4.3 to 4.6		
4.3. Were important co-interventions balanced across intervention groups?		Y / PY / PN / N / NI
4.4. Was the intervention implemented successfully for most participants?	No dropouts, injuries, etc reported.	Y / PY / PN / N / NI
4.5. Did study participants adhere to the assigned intervention regimen?		Y / PY / PN / N / NI
4.6. **If N/PN to 4.3, 4.4 or 4.5**: Was an appropriate analysis used to estimate the effect of starting and adhering to the intervention?		NA / Y / PY / PN / N / NI
Risk of bias judgement		Low / Moderate / Serious / Critical / NI
Optional: What is the predicted direction of bias due to deviations from the intended interventions?		Favours experimental / Favours comparator / Towards null /Away from null / Unpredictable

Bias due to missing data		
5.1 Were outcome data available for all, or nearly all, participants?	Only group averages were reported. But considering no dropouts were given it is likely data was available for most participants.	Y / PY / PN / N / NI

5.2 Were participants excluded due to missing data on intervention status?		Y / PY / PN / N / NI
5.3 Were participants excluded due to missing data on other variables needed for the analysis?		Y / PY / PN / N / NI
5.4 **If PN/N to 5.1, or Y/PY to 5.2 or 5.3**: Are the proportion of participants and reasons for missing data similar across interventions?		NA / Y / PY / PN / N / NI
5.5 **If PN/N to 5.1, or Y/PY to 5.2 or 5.3**: Is there evidence that results were robust to the presence of missing data?		NA / Y / PY / PN / N / NI
Risk of bias judgement	Only group averages were reported. But considering no dropouts were given it is likely data was available for most participants.	Low / Moderate / Serious / Critical / NI
Optional: What is the predicted direction of bias due to missing data?		Favours experimental / Favours comparator / Towards null /Away from null / Unpredictable

Bias in measurement of outcomes		
6.1 Could the outcome measure have been influenced by knowledge of the intervention received?	Some influencing of HR can occur (arousal). But rather unlikely with semi-professional athletes who are used to training and attention.	Y / PY / PN / N / NI
6.2 Were outcome assessors aware of the intervention received by study participants?	This is inherent to this type of research. Furthermore, outcome measures are captured automatically.	Y / PY / PN / N / NI
6.3 Were the methods of outcome assessment comparable across intervention groups?		Y / PY / PN / N / NI
6.4 Were any systematic errors in measurement of the outcome related to intervention received?	1 Hz GPS measurements has been deemed inaccurate in the literature. For high-intensity intermittent team sports with COD, <5Hz is OK. However, this was equal for all participants. Therefore a (systematic or random) non-differential measurement error, affecting precision without causing bias.	Y / PY / PN / N / NI
Risk of bias judgement		Low / Moderate / Serious / Critical / NI
Optional: What is the predicted direction of bias due to measurement of outcomes?		Favours experimental / Favours comparator / Towards null /Away from null / Unpredictable

Bias in selection of the reported result		
Is the reported effect estimate likely to be selected, on the basis of the results, from... 7.1. ... multiple outcome *measurements* within the outcome domain?	Kinematics; provides different outcome measures, but all measured through gps. Perceptual; one scale (RPE). Physiological; HR through monitor, blood lactate through blood lactate analyser. But same effect estimates used for all dependable variables.	Y / PY / PN / N / NI
7.2 ... multiple *analyses* of the intervention-outcome relationship?	All dependent variables were analysed with 2-way ANOVA. Pearson's correlation was used for relation relative pitch area and SSG demands.	Y / PY / PN / N / NI
7.3 ... different *subgroups*?		Y / PY / PN / N / NI
Risk of bias judgement	Confusingly, the kinematic and physiological outcomes reported on the SSG formats seems pooled together, not allowing for a differentiated and practically useful view on effects actual formats, i.e. player number x pitch size. Only between pitch sizes, or between player numbers.	Low / Moderate / Serious / Critical / NI
Optional: What is the predicted direction of bias due to selection of the reported result?		Favours experimental / Favours comparator / Towards null /Away from null / Unpredictable

Overall bias		
Risk of bias judgement		Low / Moderate / Serious / Critical / NI
Optional: What is the overall predicted direction of bias for this outcome?		Favours experimental / Favours comparator / Towards null /Away from null / Unpredictable

ROBINS-I tool (Stage II): For each study: Differences between experienced and novice rugby union players during small-sided games (Vaz et al. (2012))

Specify a target randomized trial specific to the study

Design	Individually randomized / Cluster randomized / Matched (e.g. cross-over)
Participants	Male rugby union players
Experimental intervention	Comparison between novice and experienced players for physical, kinematic, physiological, and game-performance outcomes in 6 vs. 6 SSGs
Comparator	Novice vs. experienced players

Is your aim for this study…?

- ☐ to assess the effect of *assignment to* intervention
- ☐ to assess the effect of *starting and adhering to* intervention

324

Specify the outcome

Specify which outcome is being assessed for risk of bias (typically from among those earmarked for the Summary of Findings table). Specify whether this is a proposed benefit or harm of intervention.

Benefits: physiological variables, physical variables, kinematical variables, and performance indicators

Specify the numerical result being assessed

In case of multiple alternative analyses being presented, specify the numeric result (e.g. RR = 1.52 (95% CI 0.83 to 2.77) and/or a reference (e.g. to a table, figure or paragraph) that uniquely defines the result being assessed.

F at $\rho<.05$, and ES (η^2) is also reported for %HR_{MAX}, GPS, and technical measures. Added, Cliff's delta (ES) and Z-scores for technical outcomes.

Preliminary consideration of confounders

Complete a row for each important confounding domain (i) listed in the review protocol; and (ii) relevant to the setting of this particular study, or which the study authors identified as potentially important.

"Important" confounding domains are those for which, in the context of this study, adjustment is expected to lead to a clinically important change in the estimated effect of the intervention. "Validity" refers to whether the confounding variable or variables fully measure the domain, while "reliability" refers to the precision of the measurement (more measurement error means less reliability).

(i) Confounding domains listed in the review protocol				
Confounding domain	Measured variable(s)	Is there evidence that controlling for this variable was unnecessary?*	Is the confounding domain measured validly and reliably by this variable (or these variables)?	OPTIONAL: Is failure to adjust for this variable (alone) expected to favour the experimental intervention or the comparator?
Coach's subjective assessment of players' overall performance level → channeling bias, allocation bias	Randomisation Or identical exposure per player to SSGs	No. No direct evidence of influence on experimental design from coaching staff, but allocation procedure is missing so coach interference is plausible.	Yes / No / No information	Favour experimental / Favour comparator / No information
Overlapping roles (investigator- coach) (= Conflict of Interest) → inclusive bias (due to convenience sampling), observer bias, performance bias, reporting bias	Concealment of allocation to SSGs, Randomisation, Identical exposure per player to SSGs, Or statement of neutrality	Yes, no evidence of overlapping roles.	Yes / No / No information	Favour experimental / Favour comparator / No information
Players' Lifestyle factors (sleep, fatigue, stress, smoking, diet, activity levels)	Randomisation Or equal exposure per player to SSGs	No. Standardisation of some procedure variables (protocol). But no evidence of randomisation into teams or equal exposure.	Yes / No / No information	Favour experimental / Favour comparator / No information
Players' characteristics (age, body composition, baseline fitness level)	Clear measurement of these characteristics at baseline, Randomisation, Matching, Or equal exposure per player to SSGs	Yes, differences in characteristics are (partly) inherent to the setup of the experiment. Some measurements done.	Yes / No / No information	Favour experimental / Favour comparator / No information

Talent (inherent skill level)	Randomisation, Objective skill test, Or equal exposure per player to SSGs	No. See former. However, no objective skill test or randomisation. And playing experience isn't necessarily related to inherent talent. Furthermore, no playing level was reported.	Yes / No / No information	Favour experimental / Favour comparator / No information
Playing position (e.g. Backs vs. forwards)	Randomisation or Matched and cross-over design	No.	Yes / No / No information	Favour experimental / Favour comparator / No information

(ii) Additional confounding domains relevant to the setting of this particular study, or which the study authors identified as important				
Confounding domain	Measured variable(s)	Is there evidence that controlling for this variable was unnecessary?*	Is the confounding domain measured validly and reliably by this variable (or these variables)?	OPTIONAL: Is failure to adjust for this variable (alone) expected to favour the experimental intervention or the comparator?
			Yes / No / No information	Favour experimental / Favour comparator / No information

* In the context of a particular study, variables can be demonstrated not to be confounders and so not included in the analysis: (a) if they are not predictive of the outcome; (b) if they are not predictive of intervention; or (c) because adjustment makes no or minimal difference to the estimated effect of the primary parameter. Note that "no statistically significant association" is not the same as "not predictive".

Preliminary consideration of co-interventions

Complete a row for each important co-intervention (i) listed in the review protocol; and (ii) relevant to the setting of this particular study, or which the study authors identified as important.

"Important" co-interventions are those for which, in the context of this study, adjustment is expected to lead to a clinically important change in the estimated effect of the intervention.

(i) Co-interventions listed in the review protocol		
Co-intervention	Is there evidence that controlling for this co-intervention was unnecessary (e.g. because it was not administered)?	Is presence of this co-intervention likely to favour outcomes in the experimental intervention or the comparator
TRAINING STRUCTURE • Non-conditioning training • Timing of conditioning training standardized (on weekly and daily level) for all participants? • Timing within training standardized (groups receive condition at the same time within training?) • Training content (activities) standardized (warm-up effect, fatigue effect)?	Yes, within testing procedure is standardised and well reported. Exact timing of testing (in the week or day) was not reported, but plausibly equal for both groups.	Favour experimental / Favour comparator / No information
PRE- TRAINING PREPARATION & NUTRITION Club meals, caffeine, massage, foam rolling,… needs to be equal for groups. IF any.	Yes. Was not reported controlled for, but plausibly there was no organised pre-training procedure. -> Player's lifestyle (=confounding)	Favour experimental / Favour comparator / No information
		Favour experimental / Favour comparator / No information

(ii) Additional co-interventions relevant to the setting of this particular study, or which the study authors identified as important		
Co-intervention	Is there evidence that controlling for this co-intervention was unnecessary (e.g. because it was not administered)?	Is presence of this co-intervention likely to favour outcomes in the experimental intervention or the comparator

Sessions were filmed. Could cause performance distortion. (arousal, stress)	Yes. If any effect, this was administered to all players. Investigation was into differences between subgroups, not necessarily absolute measured numbers.	Favour experimental / Favour comparator / No information

Risk of bias assessment

Responses underlined in green are potential markers for low risk of bias, and responses in red are potential markers for a risk of bias. Where questions relate only to sign posts to other questions, no formatting is used.

Signalling questions	Description	Response options
Bias due to confounding		
1.1 Is there potential for confounding of the effect of intervention in this study? **If N/PN to 1.1:** the study can be considered to be at low risk of bias due to confounding and no further signalling questions need be considered	• Coach's subjective assessment of players' overall performance level → channeling bias, allocation bias • Players' Lifestyle factors (sleep, fatigue, stress, smoking, diet, activity levels) • Talent (inherent skill level) • Playing position (e.g. Backs vs. forwards)	Y / PY / PN / N
If Y/PY to 1.1: determine whether there is a need to assess time-varying confounding:		
1.2. Was the analysis based on splitting participants' follow up time according to intervention received? **If N/PN**, answer questions relating to baseline confounding (1.4 to 1.6) **If Y/PY**, go to question 1.3.		NA / Y / PY / PN / N / NI
1.3. Were intervention discontinuations or switches likely to be related to factors that are prognostic for the outcome? **If N/PN**, answer questions relating to baseline confounding (1.4 to 1.6) **If Y/PY**, answer questions relating to both baseline and time-varying confounding (1.7 and 1.8)		NA / Y / PY / PN / N / NI

Questions relating to baseline confounding only		
1.4. Did the authors use an appropriate analysis method that controlled for all the important confounding domains?	The confounders cannot be controlled for through analysis methods.	NA / Y / PY / PN / N / NI

1.5. **If Y/PY to 1.4**: Were confounding domains that were controlled for measured validly and reliably by the variables available in this study?		NA / Y / PY / PN / N / NI
1.6. Did the authors control for any post-intervention variables that could have been affected by the intervention?		NA / Y / PY / PN / N / NI
Questions relating to baseline and time-varying confounding		
1.7. Did the authors use an appropriate analysis method that controlled for all the important confounding domains and for time-varying confounding?		NA / Y / PY / PN / N / NI
1.8. **If Y/PY to 1.7**: Were confounding domains that were controlled for measured validly and reliably by the variables available in this study?		NA / Y / PY / PN / N / NI
Risk of bias judgement	Only practically correct methodology could mitigate risk of confounding. The study limited risk of confounders, but real-world application leads to inherent exposure to risk of confounders without true randomisation at all stages, and full reporting of those details.	Low / Moderate / Serious / Critical / NI
Optional: What is the predicted direction of bias due to confounding?		Favours experimental / Favours comparator / Unpredictable

Bias in selection of participants into the study		
2.1. Was selection of participants into the study (or into the analysis) based on participant characteristics observed after the start of intervention? **If N/PN to 2.1:** go to 2.4	Subgroups made based on playing experience. However, this was inherent to the objective of the study. It is not clear whether participants were sampled (and in what way) to take part in the study. Therefore, it is not clear if their characteristics were observed before or after the start of intervention. Further detail of exposure to condition (SSGs) is also missing; i.e. which player from each subgroup (novice vs. experienced) was allocated to SSGs with whom, and on what basis. Who played whom; Experienced and novices amongst themselves? Experienced vs. novices? Or mixed teams?	Y / PY / PN / N / NI
2.2. **If Y/PY to 2.1**: Were the post-intervention variables that influenced selection likely to be associated with intervention? 2.3 **If Y/PY to 2.2**: Were the post-intervention variables that influenced selection likely to be influenced by the outcome or a cause of the outcome?	There was no strict "post-intervention". But Kinematic, physiological, physical and technical variables measured (during intervention) are associated with the intervention, through being part of the hypothesis that they would differ between subgroups. Which is what was being tested. The relationship between selection variables for subgroup allocation (i.e. playing years), and the outcome variables is exactly what was being investigated.	NA / Y / PY / PN / N / NI NA / Y / PY / PN / N / NI
2.4. Do start of follow-up and start of intervention coincide for most participants?		Y / PY / PN / N / NI
2.5. **If Y/PY to 2.2 and 2.3, or N/PN to 2.4**: Were adjustment techniques used that are likely to correct for the presence of selection biases?		NA / Y / PY / PN / N / NI
Risk of bias judgement	Precise detail of how sampling occurred into the experiment, and how participant selection in the study was done, is missing. This leaves room for bias.	Low / Moderate / Serious / Critical / NI
Optional: What is the predicted direction of bias due to selection of participants into the study?		Favours experimental / Favours comparator / Towards null /Away from null / Unpredictable

Bias in classification of interventions		
3.1 Were intervention groups clearly defined?		Y / PY / PN / N / NI
3.2 Was the information used to define intervention groups recorded at the start of the intervention?		Y / PY / PN / N / NI
3.3 Could classification of intervention status have been affected by knowledge of the outcome or risk of the outcome?	Playing experience was measured in playing years. The outcome measures could have overlapped between experienced and novice players, but the classification criterium (playing years) is unambiguous.	Y / PY / PN / N / NI
Risk of bias judgement		Low / Moderate / Serious / Critical / NI
Optional: What is the predicted direction of bias due to classification of interventions?		Favours experimental / Favours comparator / Towards null /Away from null / Unpredictable

Bias due to deviations from intended interventions		
If your aim for this study is to assess the effect of assignment to intervention, answer questions 4.1 and 4.2		
4.1. Were there deviations from the intended intervention beyond what would be expected in usual practice?		Y / PY / PN / N / NI
4.2. **If Y/PY to 4.1**: Were these deviations from intended intervention unbalanced between groups *and* likely to have affected the outcome?		NA / Y / PY / PN / N / NI
If your aim for this study is to assess the effect of starting and adhering to intervention, answer questions 4.3 to 4.6		
4.3. Were important co-interventions balanced across intervention groups?		Y / PY / PN / N / NI
4.4. Was the intervention implemented successfully for most participants?	No information on attrition of dropouts. So, it could be assumed most participants successfully fulfilled the experiment.	Y / PY / PN / N / NI
4.5. Did study participants adhere to the assigned intervention regimen?		Y / PY / PN / N / NI
4.6. **If N/PN to 4.3, 4.4 or 4.5**: Was an appropriate analysis used to estimate the effect of starting and adhering to the intervention?		NA / Y / PY / PN / N / NI
Risk of bias judgement		Low / Moderate / Serious / Critical / NI

Optional: What is the predicted direction of bias due to deviations from the intended interventions?		Favours experimental / Favours comparator / Towards null /Away from null / Unpredictable

Bias due to missing data		
5.1 Were outcome data available for all, or nearly all, participants?	No information to assume otherwise.	Y / PY / PN / N / NI
5.2 Were participants excluded due to missing data on intervention status?	No such mention.	Y / PY / PN / N / NI
5.3 Were participants excluded due to missing data on other variables needed for the analysis?		Y / PY / PN / N / NI
5.4 **If PN/N to 5.1, or Y/PY to 5.2 or 5.3**: Are the proportion of participants and reasons for missing data similar across interventions?		NA / Y / PY / PN / N / NI
5.5 **If PN/N to 5.1, or Y/PY to 5.2 or 5.3**: Is there evidence that results were robust to the presence of missing data?		NA / Y / PY / PN / N / NI
Risk of bias judgement	Lack of specific information about (no) missing data.	Low / Moderate / Serious / Critical / NI
Optional: What is the predicted direction of bias due to missing data?		Favours experimental / Favours comparator / Towards null /Away from null / Unpredictable

Bias in measurement of outcomes		
6.1 Could the outcome measure have been influenced by knowledge of the intervention received?	Using specialised measurement equipment and filming (GPS, HR, video) can cause deviations from normal performance, especially when participants are not used to it (i.e. novice). In this case = novice vs. experienced; might cause unequal influence of behavior/performance. Unfortunately, participants cannot be blinded to all of it. And it is not mentioned allocation to subgroups was done in a concealed manner.	Y / PY / PN / N / NI
6.2 Were outcome assessors aware of the intervention received by study participants?	Measurements are automised, so limited influenceability. But, video-analyses was completed with manual notational system. Very high inter-rater agreement reported (lowest inter-agreement kappa = 0.93). However, no specifications on what exact system, definitions on criteria, nor information on validity, general reliability, or raters was reported. -> subjectivity could play a role!	Y / PY / PN / N / NI

6.3 Were the methods of outcome assessment comparable across intervention groups?	Yes for all measurements.	Y / PY / PN / N / NI
6.4 Were any systematic errors in measurement of the outcome related to intervention received?	GPS sampling at 5Hz. Reliability and validity check were reported, i.e. the manufacturer's (= conflict of interest). The literature suggests >5Hz to be acceptable for HIIT team sports with COD. Ideally, 10 Hz. However, this was equal for all participants. Therefore a (systematic or random) non-differential measurement error, affecting precision without causing bias.	Y / PY / PN / N / NI
Risk of bias judgement		Low / Moderate / Serious / Critical / NI
Optional: What is the predicted direction of bias due to measurement of outcomes?		Favours experimental / Favours comparator / Towards null /Away from null / Unpredictable

Bias in selection of the reported result		
Is the reported effect estimate likely to be selected, on the basis of the results, from... 7.1. ... multiple outcome *measurements* within the outcome domain?	For all outcome domains (Physical, physiological, kinematic, performance indicators) SD, F ρ, η^2 was given. For performance indicators Z and Cliff's δ was added.	Y / PY / PN / N / NI
7.2 ... multiple *analyses* of the intervention-outcome relationship?		Y / PY / PN / N / NI
7.3 ... different *subgroups*?		Y / PY / PN / N / NI
Risk of bias judgement		Low / Moderate / Serious / Critical / NI
Optional: What is the predicted direction of bias due to selection of the reported result?		Favours experimental / Favours comparator / Towards null /Away from null / Unpredictable

Overall bias		
Risk of bias judgement		Low / Moderate / Serious / Critical / NI
Optional: What is the overall predicted direction of bias for this outcome?		Favours experimental / Favours comparator / Towards null /Away from null / Unpredictable

ROBINS-I tool (Stage II): For each study: Classifying youth rugby union players by training performances (Vaz, Figueira, & Gonçalves (2015))

Specify a target randomized trial specific to the study

Design	Individually randomized / Cluster randomized / Matched (e.g. cross-over)
Participants	Male rugby union players
Experimental intervention	Analysis of youth rugby union training variables for performance-based classification
Comparator	U16 vs. U18

Is your aim for this study…?

☐ to assess the effect of *assignment to* intervention
☐ to assess the effect of *starting and adhering to* intervention

334

Specify the outcome

Specify which outcome is being assessed for risk of bias (typically from among those earmarked for the Summary of Findings table). Specify whether this is a proposed benefit or harm of intervention.

Benefits: physiological variables and kinematic variables

Specify the numerical result being assessed

In case of multiple alternative analyses being presented, specify the numeric result (e.g. RR = 1.52 (95% CI 0.83 to 2.77) and/or a reference (e.g. to a table, figure or paragraph) that uniquely defines the result being assessed.

F at $\rho<.05$ and ES= sign. but weak ($\eta^2 \leq .04$), moderate ($.04 \leq \eta^2 \leq .36$), or strong ($\eta^2 > .36$) for $\%HR_{MAX}$, and GPS outcome.

Preliminary consideration of confounders

Complete a row for each important confounding domain (i) listed in the review protocol; and (ii) relevant to the setting of this particular study, or which the study authors identified as potentially important.

"Important" confounding domains are those for which, in the context of this study, adjustment is expected to lead to a clinically important change in the estimated effect of the intervention. "Validity" refers to whether the confounding variable or variables fully measure the domain, while "reliability" refers to the precision of the measurement (more measurement error means less reliability).

(i) Confounding domains listed in the review protocol				
Confounding domain	Measured variable(s)	Is there evidence that controlling for this variable was unnecessary?*	Is the confounding domain measured validly and reliably by this variable (or these variables)?	OPTIONAL: Is failure to adjust for this variable (alone) expected to favour the experimental intervention or the comparator?
Coach's subjective assessment of players' overall performance level → channeling bias, allocation bias	Randomisation Or identical exposure per player to (all) SSG forms	Yes. Observational study; trainings, including SSG forms, were developed by coaching staff, and delivered to all players. Possibly not equal or randomised exposure to all training elements, but this is already within the condition (i.e. U16/U18 group). ->does not impact allocation to condition (whole training session), age category does. But does potentially impact outcome.	Yes / No / No information	Favour experimental / Favour comparator / No information
Overlapping roles (investigator- coach) (= Conflict of Interest) → inclusive bias (due to convenience sampling), observer bias, performance bias, reporting bias	Concealment of allocation to SSGs, Randomisation, Identical exposure per player to SSGs, Or statement of neutrality	Yes, report suggests no overlapping roles.	Yes / No / No information	Favour experimental / Favour comparator / No information
Players' Lifestyle factors (sleep, fatigue, stress, smoking, diet, activity levels)	Randomisation Or equal exposure per player to SSGs	Yes. Inherent to study set-up, allocation to condition (whole training sessions) was, within rugby population, solely age-	Yes / No / No information	Favour experimental / Favour comparator / No information

		based. So only potentially prognostic of outcome, but not allocation to condition. Details on within-group exposure to SSGs not available. Could be influenced by players' lifestyle.		
Players' characteristics (age, body composition, baseline fitness level)	Clear measurement of these characteristics at baseline, Randomisation, Matching, Or equal exposure per player to SSGs	Yes, differences in characteristics are inherent to the setup of study. Allocation based on age. Baseline characteristics were measured and reported. Details on within-group exposure to SSGs not available. Could be influenced by players' characteristics.	Yes / No / No information	Favour experimental / Favour comparator / No information
Talent (inherent skill level)	Randomisation, Objective skill test, Or equal exposure per player to SSGs	Yes. Inherent to study set-up, allocation to condition was, within rugby population, solely age-based. So only potentially prognostic of outcome, but not allocation to condition. Details on within-group exposure to SSGs not available. Could be influenced by players' talent.	Yes / No / No information	Favour experimental / Favour comparator / No information
Playing position (e.g. Backs vs. forwards)	Randomisation or Matched and cross-over design	Yes. Inherent to study set-up, allocation to condition was, within rugby population, solely age-based. So only potentially prognostic of outcome, but not allocation to condition. Details on within-group exposure to SSGs not available. Could be influenced by players' postions.	Yes / No / No information	Favour experimental / Favour comparator / No information

(ii) Additional confounding domains relevant to the setting of this particular study, or which the study authors identified as important				
Confounding domain	Measured variable(s)	Is there evidence that controlling for this variable was unnecessary?*	Is the confounding domain measured validly and reliably by this variable (or these variables)?	OPTIONAL: Is failure to adjust for this variable (alone) expected to favour the experimental intervention or the comparator?
			Yes / No / No information	Favour experimental / Favour comparator / No information

* In the context of a particular study, variables can be demonstrated not to be confounders and so not included in the analysis: (a) if they are not predictive of the outcome; (b) if they are not predictive of intervention; or (c) because adjustment makes no or minimal difference to the estimated effect of the primary parameter. Note that "no statistically significant association" is not the same as "not predictive".

Preliminary consideration of co-interventions

Complete a row for each important co-intervention (i) listed in the review protocol; and (ii) relevant to the setting of this particular study, or which the study authors identified as important.

"Important" co-interventions are those for which, in the context of this study, adjustment is expected to lead to a clinically important change in the estimated effect of the intervention.

(i) Co-interventions listed in the review protocol		
Co-intervention	Is there evidence that controlling for this co-intervention was unnecessary (e.g. because it was not administered)?	Is presence of this co-intervention likely to favour outcomes in the experimental intervention or the comparator
TRAINING STRUCTURE • Non-conditioning training • Timing of conditioning training standardized (on weekly and daily level) for all participants? • Timing within training standardized (groups receive condition at the same time within training?) • Training content (activities) standardized (warm-up effect, fatigue effect)?	Yes, partly. Starting procedure and ending procedure within the observed training sessions were standardised for content for both groups. So was timing of training and pitch characteristics. Environmental conditions were also reported similar.	Favour experimental / Favour comparator / No information
PRE- TRAINING PREPARATION & NUTRITION Club meals, caffeine, massage, foam rolling,… needs to be equal for groups. IF any.	Yes. Was not reported controlled for, but plausibly there was no organised pre-training procedure. -> Player's lifestyle (=confounding)	Favour experimental / Favour comparator / No information

(ii) Additional co-interventions relevant to the setting of this particular study, or which the study authors identified as important		
Co-intervention	Is there evidence that controlling for this co-intervention was unnecessary (e.g. because it was not administered)?	Is presence of this co-intervention likely to favour outcomes in the experimental intervention or the comparator
The actual intervention (training session core) was different (not detailed) for both groups, while being evaluated on identical criteria, using the same parameters. Two different baseline conditions. To then use differences in these performance outcomes to classify individuals across both groups according to these performance outcomes!?	No. The core of each group training (U16/U18 respectively) was dissimilar from one another. Exact details could not be reported. Per definition, this makes the exposure to each training a co-intervention in comparison to the other group's.	Favour experimental / Favour comparator / No information

Risk of bias assessment

Responses underlined in green are potential markers for low risk of bias, and responses in red are potential markers for a risk of bias. Where questions relate only to sign posts to other questions, no formatting is used.

Signalling questions	Description	Response options
Bias due to confounding		
1.1 Is there potential for confounding of the effect of intervention in this study? **If N/PN to 1.1:** the study can be considered to be at low risk of bias due to confounding and no further signalling questions need be considered	All participants were from 1 team. But allocation to training condition was specifically age-based. Therefore, other potential confounders become irrelevant, as they are built in and not prognostic for intervention allocation. Only for outcome. (There might be an influence of confounding within each intervention group, as exposure within groups was not reported in detail. But again, this did not influence allocation to groups)	Y / PY / PN / N
If Y/PY to 1.1: determine whether there is a need to assess time-varying confounding:		
1.2. Was the analysis based on splitting participants' follow up time according to intervention received? **If N/PN**, answer questions relating to baseline confounding (1.4 to 1.6) **If Y/PY**, go to question 1.3.		NA / Y / PY / PN / N / NI

1.3. Were intervention discontinuations or switches likely to be related to factors that are prognostic for the outcome? **If N/PN**, answer questions relating to baseline confounding (1.4 to 1.6) **If Y/PY**, answer questions relating to both baseline and time-varying confounding (1.7 and 1.8)	Limited (indirect) information available: 28 players form 1 team; 13 U16s, 15 U18s. Both groups received similar, but non-identical interventions. 2 weeks, 8 sessions, exact SSG formats unspecified; reported n=103. 103/28= 3.68? => unequal exposure per player. No way to track down exposure to conditions-> unreported discontinuation within condition groups plausible. If there were any, they could have impacted the outcome indeed.	NA / Y / PY / PN / N / NI

Questions relating to baseline confounding only		
1.4. Did the authors use an appropriate analysis method that controlled for all the important confounding domains?		NA / Y / PY / PN / N / NI
1.5. **If Y/PY to 1.4**: Were confounding domains that were controlled for measured validly and reliably by the variables available in this study?		NA / Y / PY / PN / N / NI
1.6. Did the authors control for any post-intervention variables that could have been affected by the intervention?		NA / Y / PY / PN / N / NI
Questions relating to baseline and time-varying confounding		
1.7. Did the authors use an appropriate analysis method that controlled for all the important confounding domains and for time-varying confounding?		NA / Y / PY / PN / N / NI
1.8. **If Y/PY to 1.7**: Were confounding domains that were controlled for measured validly and reliably by the variables available in this study?		NA / Y / PY / PN / N / NI
Risk of bias judgement		Low / Moderate / Serious / Critical / NI
Optional: What is the predicted direction of bias due to confounding?		Favours experimental / Favours comparator / Unpredictable

Bias in selection of participants into the study		
2.1. Was selection of participants into the study (or into the analysis) based on participant characteristics observed after the start of intervention? **If N/PN to 2.1:** go to 2.4	Although all participants were from 1 team, and bound by age for allocation to condition, within conditions, the selection for SSGs is unclear! Also see description 1.3.	Y / PY / PN / N / NI

2.2. **If Y/PY to 2.1**: Were the post-intervention variables that influenced selection likely to be associated with intervention? 2.3 **If Y/PY to 2.2**: Were the post-intervention variables that influenced selection likely to be influenced by the outcome or a cause of the outcome?	Selection for specific SSGs, within each condition, is unknown. And intervention was coach-led. It is very plausible some players got less exposure due to any number of subjective reasons, e.g. less talented, fitter, better, et. This will skew the average outcomes.	NA / Y / PY / PN / N / NI NA / Y / PY / PN / N / NI
2.4. Do start of follow-up and start of intervention coincide for most participants?		Y / PY / PN / N / NI
2.5. **If Y/PY to 2.2 and 2.3, or N/PN to 2.4**: Were adjustment techniques used that are likely to correct for the presence of selection biases?		NA / Y / PY / PN / N / NI
Risk of bias judgement		Low / Moderate / Serious / Critical / NI
Optional: What is the predicted direction of bias due to selection of participants into the study?		Favours experimental / Favours comparator / Towards null /Away from null / Unpredictable

Bias in classification of interventions		
3.1 Were intervention groups clearly defined?	U16 and U18 male rugby union players from the same youth rugby team.	Y / PY / PN / N / NI
3.2 Was the information used to define intervention groups recorded at the start of the intervention?		Y / PY / PN / N / NI
3.3 Could classification of intervention status have been affected by knowledge of the outcome or risk of the outcome?		Y / PY / PN / N / NI
Risk of bias judgement		Low / Moderate / Serious / Critical / NI
Optional: What is the predicted direction of bias due to classification of interventions?		Favours experimental / Favours comparator / Towards null /Away from null / Unpredictable

Bias due to deviations from intended interventions		
If your aim for this study is to assess the effect of assignment to intervention, answer questions 4.1 and 4.2		
4.1. Were there deviations from the intended intervention beyond what would be expected in usual practice?		Y / PY / PN / N / NI

4.2. **If Y/PY to 4.1**: Were these deviations from intended intervention unbalanced between groups *and* likely to have affected the outcome?		NA / Y / PY / PN / N / NI
If your aim for this study is to assess the effect of starting and adhering to intervention, answer questions 4.3 to 4.6		
4.3. Were important co-interventions balanced across intervention groups?	Baseline conditions were different for subgroups. To draw correct conclusions, all participants should have been exposed to identical training! One cannot evaluate similarities in training performances, based on different training conditions.	Y / PY / PN / N / NI
4.4. Was the intervention implemented successfully for most participants?		Y / PY / PN / N / NI
4.5. Did study participants adhere to the assigned intervention regimen?	Probably most of the participants.	Y / PY / PN / N / NI
4.6. **If N/PN to 4.3, 4.4 or 4.5**: Was an appropriate analysis used to estimate the effect of starting and adhering to the intervention?		NA / Y / PY / PN / N / NI
Risk of bias judgement	The basic study set-up seems flawed, voiding the validity of the conclusions that were aimed for in terms of grouping players by performance.	Low / Moderate / Serious / Critical / NI
Optional: What is the predicted direction of bias due to deviations from the intended interventions?		Favours experimental / Favours comparator / Towards null /Away from null / Unpredictable

Bias due to missing data		
5.1 Were outcome data available for all, or nearly all, participants?	Likely not all participants had equal exposure to SSGs within groups. However, n=103 infers enough data was sampled.	Y / PY / PN / N / NI
5.2 Were participants excluded due to missing data on intervention status?	Subgroups were well-defined and trained separately. So unlikely.	Y / PY / PN / N / NI
5.3 Were participants excluded due to missing data on other variables needed for the analysis?		Y / PY / PN / N / NI
5.4 **If PN/N to 5.1, or Y/PY to 5.2 or 5.3**: Are the proportion of participants and reasons for missing data similar across interventions?		NA / Y / PY / PN / N / NI

5.5 **If PN/N to 5.1, or Y/PY to 5.2 or 5.3**: Is there evidence that results were robust to the presence of missing data?		NA / Y / PY / PN / N / NI
Risk of bias judgement	Not enough clear information regarding handling missing data to draw strong conclusions.	Low / Moderate / Serious / Critical / NI
Optional: What is the predicted direction of bias due to missing data?		Favours experimental / Favours comparator / Towards null /Away from null / Unpredictable

Bias in measurement of outcomes		
6.1 Could the outcome measure have been influenced by knowledge of the intervention received?	Using specialised measurement equipment (GPS, HR) can cause deviations from normal performance, especially when participants are not used to it (i.e. youth). Coaches might also be inducing bias. Report suggests that intervention was not concealed.	Y / PY / PN / N / NI
6.2 Were outcome assessors aware of the intervention received by study participants?	Observational research though. Automised measurements, limited influenceability.	Y / PY / PN / N / NI
6.3 Were the methods of outcome assessment comparable across intervention groups?		Y / PY / PN / N / NI
6.4 Were any systematic errors in measurement of the outcome related to intervention received?	GPS sampling at 5Hz. Some sources were provided as argumentation. However, the literature suggests >5Hz to be acceptable for HIIT team sports with COD. Ideally, 10 Hz. Nevertheless, this was equal for all participants. Therefore a (systematic or random) non-differential measurement error, affecting precision without causing bias.	Y / PY / PN / N / NI
Risk of bias judgement		Low / Moderate / Serious / Critical / NI
Optional: What is the predicted direction of bias due to measurement of outcomes?		Favours experimental / Favours comparator / Towards null /Away from null / Unpredictable

Bias in selection of the reported result		
Is the reported effect estimate likely to be selected, on the basis of the results, from...		
7.1. ... multiple outcome *measurements* within the outcome domain?	For all outcome domains (physiological, kinematic) SD, F ρ, η^2 was given.	Y / PY / PN / N / NI
7.2 ... multiple *analyses* of the intervention-outcome relationship?	For grouping variables predictor importance (PI) was provided (%)	Y / PY / PN / N / NI

7.3 ... different *subgroups*?	Same for both subgroups	Y / PY / PN / N / NI
Risk of bias judgement		Low / Moderate / Serious / Critical / NI
Optional: What is the predicted direction of bias due to selection of the reported result?		Favours experimental / Favours comparator / Towards null /Away from null / Unpredictable

Overall bias		
Risk of bias judgement	Set up of experiment is essentially flawed. Report is very subpar when it comes to depth of information, construction of rational, and linguistics.	Low / Moderate / Serious / Critical / NI
Optional: What is the overall predicted direction of bias for this outcome?		Favours experimental / Favours comparator / Towards null /Away from null / Unpredictable

ROBINS-I tool (Stage II): For each study: Influence of different small-sided games on physical and physiological demands in rugby union players (Vaz et al. (2016))

Specify a target randomized trial specific to the study

Design	Individually randomized / Cluster randomized / Matched (e.g. cross-over)
Participants	National level male rugby union players
Experimental intervention	Comparison of the physical and physiological demands in different rugby small-sided game formats
Comparator	1x1 vs. 2x1 vs. 7x7 (S) vs. 7x7 (L)

Is your aim for this study…?

☐ to assess the effect of *assignment to* intervention

☐ to assess the effect of *starting and adhering to* intervention

345

Specify the outcome

Specify which outcome is being assessed for risk of bias (typically from among those earmarked for the Summary of Findings table). Specify whether this is a proposed benefit or harm of intervention.

Benefits: physiological variables and kinematic variables

Specify the numerical result being assessed

In case of multiple alternative analyses being presented, specify the numeric result (e.g. RR = 1.52 (95% CI 0.83 to 2.77) and/or a reference (e.g. to a table, figure or paragraph) that uniquely defines the result being assessed.

F at $\rho<.05$ for %HR_{MAX}, and GPS outcome.

Preliminary consideration of confounders

Complete a row for each important confounding domain (i) listed in the review protocol; and (ii) relevant to the setting of this particular study, or which the study authors identified as potentially important.

"Important" confounding domains are those for which, in the context of this study, adjustment is expected to lead to a clinically important change in the estimated effect of the intervention. "Validity" refers to whether the confounding variable or variables fully measure the domain, while "reliability" refers to the precision of the measurement (more measurement error means less reliability).

(i) Confounding domains listed in the review protocol				
Confounding domain	Measured variable(s)	Is there evidence that controlling for this variable was unnecessary?*	Is the confounding domain measured validly and reliably by this variable (or these variables)?	OPTIONAL: Is failure to adjust for this variable (alone) expected to favour the experimental intervention or the comparator?
Coach's subjective assessment of players' overall performance level → channeling bias, allocation bias	Randomisation Or identical exposure per player to SSGs	No. Coaching staff and players agreed to the SSG protocols, but it is not outlined randomisation for allocation, or equal exposure to different SSGs was used. Furthermore, average player count on training was 26 ± 2, whereas n= 14, inferring not al players were used.	Yes / No / No information	Favour experimental / Favour comparator / No information
Overlapping roles (investigator- coach) (= Conflict of Interest) → inclusive bias (due to convenience sampling), observer bias, performance bias, reporting bias	Concealment of allocation to SSGs, Randomisation, Identical exposure per player to SSGs, Or statement of neutrality	Yes. Clear declaration of no conflicting interests.	Yes / No / No information	Favour experimental / Favour comparator / No information
Players' Lifestyle factors (sleep, fatigue, stress, smoking, diet, activity levels)	Randomisation Or equal exposure per player to SSGs	No. Elite level rugby union players. Dietary intake controlled by federation nutritionist. Despite this, it is not possible to account for all lifestyle factors of individual players, apart from	Yes / No / No information	Favour experimental / Favour comparator / No information

		randomisation or exact equal exposure of every player.		
Players' characteristics (age, body composition, baseline fitness level)	Clear measurement of these characteristics at baseline, Randomisation, Matching, Or equal exposure per player to SSGs	No. Most anthropomorphic tested. But no fitness characteristics. Might lead to incl/excl to some SSG formats.	Yes / No / No information	Favour experimental / Favour comparator / No information
Talent (inherent skill level)	Randomisation, Objective skill test, Or equal exposure per player to SSGs	No. No objective skill test or randomisation. Although all participants were from 1 team, the selection for SSGs is unclear.	Yes / No / No information	Favour experimental / Favour comparator / No information
Playing position (e.g. Backs vs. forwards)	Randomisation or Matched and cross-over design	No. See former.	Yes / No / No information	Favour experimental / Favour comparator / No information

(ii) Additional confounding domains relevant to the setting of this particular study, or which the study authors identified as important				
Confounding domain	Measured variable(s)	Is there evidence that controlling for this variable was unnecessary?*	Is the confounding domain measured validly and reliably by this variable (or these variables)?	OPTIONAL: Is failure to adjust for this variable (alone) expected to favour the experimental intervention or the comparator?
			Yes / No / No information	Favour experimental / Favour comparator / No information

* In the context of a particular study, variables can be demonstrated not to be confounders and so not included in the analysis: (a) if they are not predictive of the outcome; (b) if they are not predictive of intervention; or (c) because adjustment makes no or minimal difference to the estimated effect of the primary parameter. Note that "no statistically significant association" is not the same as "not predictive".

Preliminary consideration of co-interventions

Complete a row for each important co-intervention (i) listed in the review protocol; and (ii) relevant to the setting of this particular study, or which the study authors identified as important.

"Important" co-interventions are those for which, in the context of this study, adjustment is expected to lead to a clinically important change in the estimated effect of the intervention.

(i) Co-interventions listed in the review protocol		
Co-intervention	Is there evidence that controlling for this co-intervention was unnecessary (e.g. because it was not administered)?	Is presence of this co-intervention likely to favour outcomes in the experimental intervention or the comparator
TRAINING STRUCTURE • Non-conditioning training • Timing of conditioning training standardized (on weekly and daily level) for all participants? • Timing within training standardized (groups receive condition at the same time within training?) • Training content (activities) standardized (warm-up effect, fatigue effect)?	No. Quasi-standardisation of some aspects; same period of day (18:30 h – 21:00 h), natural turf pitch, similar environmental conditions, standardised training start and ending. No details on core activities of training apart from SSGs (only 15 mins). It is understood 1 session = 1 SSG format. Otherwise, differences between various SSGs within sessions could have arisen too.	Favour experimental / Favour comparator / No information
PRE- TRAINING PREPARATION & NUTRITION Club meals, caffeine, massage, foam rolling,… needs to be equal for groups. IF any.	Yes. Quasi-standardisation of some aspects; Food and fluid intake supervised, regular post-match recovery	Favour experimental / Favour comparator / No information

(ii) Additional co-interventions relevant to the setting of this particular study, or which the study authors identified as important		
Co-intervention	Is there evidence that controlling for this co-intervention was unnecessary (e.g. because it was not administered)?	Is presence of this co-intervention likely to favour outcomes in the experimental intervention or the comparator

		Favour experimental / Favour comparator / No information

Risk of bias assessment

Responses underlined in green are potential markers for low risk of bias, and responses in red are potential markers for a risk of bias. Where questions relate only to sign posts to other questions, no formatting is used.

Signalling questions	Description	Response options
Bias due to confounding		
1.1 Is there potential for confounding of the effect of intervention in this study? **If N/PN to 1.1:** the study can be considered to be at low risk of bias due to confounding and no further signalling questions need be considered	• Coach's subjective assessment of players' overall performance level → channeling bias, allocation bias • Players' lifestyle factors (sleep, fatigue, stress, smoking, diet, activity levels) • Players' characteristics (age, body composition, baseline fitness level) • Talent (inherent skill level) • Playing position (e.g. Backs vs. forwards)	Y / PY / PN / N
If Y/PY to 1.1: determine whether there is a need to assess time-varying confounding:		
1.2. Was the analysis based on splitting participants' follow up time according to intervention received? **If N/PN**, answer questions relating to baseline confounding (1.4 to 1.6) **If Y/PY**, go to question 1.3.		NA / Y / PY / PN / N / NI
1.3. Were intervention discontinuations or switches likely to be related to factors that are prognostic for the outcome? **If N/PN**, answer questions relating to baseline confounding (1.4 to 1.6) **If Y/PY**, answer questions relating to both baseline and time-varying confounding (1.7 and 1.8)	More players then SSG participants. No information concerning discontinuations or drop-outs.	NA / Y / PY / PN / N / NI

Questions relating to baseline confounding only		
1.4. Did the authors use an appropriate analysis method that controlled for all the important confounding domains?		NA / Y / PY / PN / N / NI

1.5. **If Y/PY to 1.4**: Were confounding domains that were controlled for measured validly and reliably by the variables available in this study?		NA / Y / PY / PN / N / NI
1.6. Did the authors control for any post-intervention variables that could have been affected by the intervention?		NA / Y / PY / PN / N / NI
Questions relating to baseline and time-varying confounding		
1.7. Did the authors use an appropriate analysis method that controlled for all the important confounding domains and for time-varying confounding?		NA / Y / PY / PN / N / NI
1.8. **If Y/PY to 1.7**: Were confounding domains that were controlled for measured validly and reliably by the variables available in this study?	Declaration of no conflict of interest.	NA / Y / PY / PN / N / NI
Risk of bias judgement	No mention of randomised allocation, from available players, to specific SSGs.	Low / Moderate / Serious / Critical / NI
Optional: What is the predicted direction of bias due to confounding?		Favours experimental / Favours comparator / Unpredictable

Bias in selection of participants into the study		
2.1. Was selection of participants into the study (or into the analysis) based on participant characteristics observed after the start of intervention?	No information reported on players assigned to specific SSGs.	Y / PY / PN / N / NI
If N/PN to 2.1: go to 2.4		
2.2. **If Y/PY to 2.1**: Were the post-intervention variables that influenced selection likely to be associated with intervention?		NA / Y / PY / PN / N / NI
2.3 **If Y/PY to 2.2**: Were the post-intervention variables that influenced selection likely to be influenced by the outcome or a cause of the outcome?		NA / Y / PY / PN / N / NI
2.4. Do start of follow-up and start of intervention coincide for most participants?	Testing: 4-week period between Oct 2012-March 2013. But no specific details on various SSG play (week per week, session per session).	Y / PY / PN / N / NI
2.5. **If Y/PY to 2.2 and 2.3, or N/PN to 2.4**: Were adjustment techniques used that are likely to correct for the presence of selection biases?	Not reported.	NA / Y / PY / PN / N / NI
Risk of bias judgement	Not enough information. If SSGs was coach-led, serious risk of selection bias.	Low / Moderate / Serious / Critical / NI

Optional: What is the predicted direction of bias due to selection of participants into the study?		Favours experimental / Favours comparator / Towards null /Away from null / Unpredictable

Bias in classification of interventions		
3.1 Were intervention groups clearly defined?	Study participants were clearly defined. It is assumed these	Y / PY / PN / N / NI
3.2 Was the information used to define intervention groups recorded at the start of the intervention?		Y / PY / PN / N / NI
3.3 Could classification of intervention status have been affected by knowledge of the outcome or risk of the outcome?	Lack of information does not allow to discard that some players might have served multiple roles, allocated to multiple SSGs, or a few, changed SSGs, if that was in fact inherent to the training session(s). However, exact outcome is unlikely to have been known due to nature of measurments.	Y / PY / PN / N / NI
Risk of bias judgement		Low / Moderate / Serious / Critical / NI
Optional: What is the predicted direction of bias due to classification of interventions?		Favours experimental / Favours comparator / Towards null /Away from null / Unpredictable

Bias due to deviations from intended interventions		
If your aim for this study is to assess the effect of assignment to intervention, answer questions 4.1 and 4.2		
4.1. Were there deviations from the intended intervention beyond what would be expected in usual practice?		Y / PY / PN / N / NI
4.2. **If Y/PY to 4.1**: Were these deviations from intended intervention unbalanced between groups *and* likely to have affected the outcome?		NA / Y / PY / PN / N / NI
If your aim for this study is to assess the effect of starting and adhering to intervention, answer questions 4.3 to 4.6		
4.3. Were important co-interventions balanced across intervention groups?	No information on core of training sessions, other than standardised start and ending, and 15 mins SSG format.	Y / PY / PN / N / NI
4.4. Was the intervention implemented successfully for most participants?	n=14 but avg. player per training was 26 ± 2. Remarkable… However, might have sufficed considering largest SSG was 7 vs. 7.	Y / PY / PN / N / NI
4.5. Did study participants adhere to the assigned intervention regimen?	No drop-outs reported.	Y / PY / PN / N / NI

4.6. **If N/PN to 4.3, 4.4 or 4.5**: Was an appropriate analysis used to estimate the effect of starting and adhering to the intervention?		NA / Y / PY / PN / N / NI
Risk of bias judgement		Low / Moderate / Serious / Critical / NI
Optional: What is the predicted direction of bias due to deviations from the intended interventions?		Favours experimental / Favours comparator / Towards null /Away from null / Unpredictable

Bias due to missing data		
5.1 Were outcome data available for all, or nearly all, participants?	No specific mention, but stats done with n=14.	Y / PY / PN / N / NI
5.2 Were participants excluded due to missing data on intervention status?		Y / PY / PN / N / NI
5.3 Were participants excluded due to missing data on other variables needed for the analysis?		Y / PY / PN / N / NI
5.4 **If PN/N to 5.1, or Y/PY to 5.2 or 5.3**: Are the proportion of participants and reasons for missing data similar across interventions?		NA / Y / PY / PN / N / NI
5.5 **If PN/N to 5.1, or Y/PY to 5.2 or 5.3**: Is there evidence that results were robust to the presence of missing data?		NA / Y / PY / PN / N / NI
Risk of bias judgement	It can be assumed enough data was available for statistical calculations done. But no specific mentions were reported regarding completeness of, or missing data.	Low / Moderate / Serious / Critical / NI
Optional: What is the predicted direction of bias due to missing data?		Favours experimental / Favours comparator / Towards null /Away from null / Unpredictable
Bias in measurement of outcomes		
6.1 Could the outcome measure have been influenced by knowledge of the intervention received?	Some influencing of HR can occur. But rather unlikely with professional athletes who are used to training and attention.	Y / PY / PN / N / NI
6.2 Were outcome assessors aware of the intervention received by study participants?	No mention of blinding of assessors. This is inherent to this type of research. Furthermore, outcome measures are captured automatically.	Y / PY / PN / N / NI
6.3 Were the methods of outcome assessment comparable across intervention groups?		Y / PY / PN / N / NI

6.4 Were any systematic errors in measurement of the outcome related to intervention received?	GPS sampling at 5Hz. Some sources were provided as argumentation. However, the literature suggests >5Hz to be acceptable for HIIT team sports with COD. Ideally, 10 Hz. However, this was equal for all participants. Therefore a (systematic or random) non-differential measurement error, affecting precision without causing bias.	Y / PY / PN / N / NI
Risk of bias judgement		Low / Moderate / Serious / Critical / NI
Optional: What is the predicted direction of bias due to measurement of outcomes?		Favours experimental / Favours comparator / Towards null /Away from null / Unpredictable

Bias in selection of the reported result		
Is the reported effect estimate likely to be selected, on the basis of the results, from... 7.1. ... multiple outcome *measurements* within the outcome domain?	For all outcome domains (physiological, kinematic) SD, F ρ, η^2 was given.	Y / PY / PN / N / NI
7.2 ... multiple *analyses* of the intervention-outcome relationship?		Y / PY / PN / N / NI
7.3 ... different *subgroups*?	Same for both subgroups	Y / PY / PN / N / NI
Risk of bias judgement		Low / Moderate / Serious / Critical / NI
Optional: What is the predicted direction of bias due to selection of the reported result?		Favours experimental / Favours comparator / Towards null /Away from null / Unpredictable

Overall bias		
Risk of bias judgement	Too much specific information is missing regarding different SSG formats in specific sessions. Critical risk of confounding bias.	Low / Moderate / Serious / Critical / NI
Optional: What is the overall predicted direction of bias for this outcome?		Favours experimental / Favours comparator / Towards null /Away from null / Unpredictable

ROBINS-I tool (Stage II): For each study: GPS comparison of training activities and game demands of professional rugby union (Tee, Lambert, & Coopoo (2016))

Specify a target randomized trial specific to the study

Design	Individually randomized / Cluster randomized / Matched (e.g. cross-over)
Participants	Professional male rugby union players
Experimental intervention	Comparison of different rugby union training forms to match demands
Comparator	Traditional endurance conditioning (TEC) vs. high-intensity interval training (HIIT) vs. game-based training (GBT) vs. game skills training (ST)

Is your aim for this study…?

☐ to assess the effect of *assignment to* intervention
☐ to assess the effect of *starting and adhering to* intervention

354

Specify the outcome

Specify which outcome is being assessed for risk of bias (typically from among those earmarked for the Summary of Findings table). Specify whether this is a proposed benefit or harm of intervention.

Benefits: kinematic variables (movement demands)

Specify the numerical result being assessed

In case of multiple alternative analyses being presented, specify the numeric result (e.g. RR = 1.52 (95% CI 0.83 to 2.77) and/or a reference (e.g. to a table, figure or paragraph) that uniquely defines the result being assessed.

ρ<.05 and Cohen's ES= 0.2 (small), 0.6 (medium), 1.2 (large), 2.0 (very large) for GPS outcome.

Preliminary consideration of confounders

Complete a row for each important confounding domain (i) listed in the review protocol; and (ii) relevant to the setting of this particular study, or which the study authors identified as potentially important.

"Important" confounding domains are those for which, in the context of this study, adjustment is expected to lead to a clinically important change in the estimated effect of the intervention. "Validity" refers to whether the confounding variable or variables fully measure the domain, while "reliability" refers to the precision of the measurement (more measurement error means less reliability).

(i) Confounding domains listed in the review protocol				
Confounding domain	Measured variable(s)	Is there evidence that controlling for this variable was unnecessary?*	Is the confounding domain measured validly and reliably by this variable (or these variables)?	OPTIONAL: Is failure to adjust for this variable (alone) expected to favour the experimental intervention or the comparator?
Coach's subjective assessment of players' overall performance level → channeling bias, allocation bias	Randomisation Or identical exposure per player to (all) SSG forms	No. Condition (1) = Whole training sessions; Results reported means included. Therefore, coach's subjective assessment (within sessions) is irrelevant. So ≠ prognostic for allocation. However, condition (2) = game. Coach's subjective assessment is inherent to selection! Possible bias.	Yes / No / No information	Favour experimental / Favour comparator / No information
Overlapping roles (investigator- coach) (= Conflict of Interest) → inclusive bias (due to convenience sampling), observer bias, performance bias, reporting bias	Concealment of allocation to SSGs, Randomisation, Identical exposure per player to SSGs, Or statement of neutrality	Yes, declaration of no potential conflicting interests.	Yes / No / No information	Favour experimental / Favour comparator / No information
Players' Lifestyle factors (sleep, fatigue, stress, smoking, diet, activity levels)	Randomisation Or equal exposure per player to SSGs	No. Despite not prognostic for training participation, lifestyle factors might influence performance. Which might lead to (no) selection for games.	Yes / No / No information	Favour experimental / Favour comparator / No information

Players' characteristics (age, body composition, baseline fitness level)	Clear measurement of these characteristics at baseline, Randomisation, Matching, Or equal exposure per player to SSGs	No. Differences in characteristics are inherent to the setup of study. Baseline characteristics were measured and reported, excl. of fitness levels. Despite not prognostic for training participation, characteristics might influence game selection. Anthropometrics = accounted for, but not fitness level.	Yes / No / No information	Favour experimental / Favour comparator / No information
Talent (inherent skill level)	Randomisation, Objective skill test, Or equal exposure per player to SSGs	No. Despite not prognostic for training participation, talent might influence performance. Which might lead to (no) selection for games.	Yes / No / No information	Favour experimental / Favour comparator / No information
Playing position (e.g. Backs vs. forwards)	Randomisation or Matched and cross-over design	Yes. Not prognostic for training session allocation. And all needed in games. Inherent to study set-up, accounted for in analysis.	Yes / No / No information	Favour experimental / Favour comparator / No information

(ii) Additional confounding domains relevant to the setting of this particular study, or which the study authors identified as important				
Confounding domain	Measured variable(s)	Is there evidence that controlling for this variable was unnecessary?*	Is the confounding domain measured validly and reliably by this variable (or these variables)?	OPTIONAL: Is failure to adjust for this variable (alone) expected to favour the experimental intervention or the comparator?
			Yes / No / No information	Favour experimental / Favour comparator / No information

* In the context of a particular study, variables can be demonstrated not to be confounders and so not included in the analysis: (a) if they are not predictive of the outcome; (b) if they are not predictive of intervention; or (c) because adjustment makes no or minimal difference to the estimated effect of the primary parameter. Note that "no statistically significant association" is not the same as "not predictive".

Preliminary consideration of co-interventions

Complete a row for each important co-intervention (i) listed in the review protocol; and (ii) relevant to the setting of this particular study, or which the study authors identified as important.

"Important" co-interventions are those for which, in the context of this study, adjustment is expected to lead to a clinically important change in the estimated effect of the intervention.

(i) Co-interventions listed in the review protocol		
Co-intervention	Is there evidence that controlling for this co-intervention was unnecessary (e.g. because it was not administered)?	Is presence of this co-intervention likely to favour outcomes in the experimental intervention or the comparator
TRAINING STRUCTURE • Non-conditioning training • Timing of conditioning training standardized (on weekly and daily level) for all participants? • Timing within training standardized (groups receive condition at the same time within training?) • Training content (activities) standardized (warm-up effect, fatigue effect)?	Partly, • Best-case real world (quasi-) randomisation: • Specific session parts standard excluded from analysis • All training types performed in pre-and in-season, and movement profiles found similar • Session times normalised But effect of timing, and cumulative fatigue effect of longer sessions on (normalised) performance output cannot be accounted for.	Favour experimental / Favour comparator / No information
PRE- TRAINING PREPARATION & NUTRITION Club meals, caffeine, massage, foam rolling,… needs to be equal for groups. IF any.	Yes. Was not reported controlled for, but professional setting.	Favour experimental / Favour comparator / No information

(ii) Additional co-interventions relevant to the setting of this particular study, or which the study authors identified as important		
Co-intervention	Is there evidence that controlling for this co-intervention was unnecessary (e.g. because it was not administered)?	Is presence of this co-intervention likely to favour outcomes in the experimental intervention or the comparator
		Favour experimental / Favour comparator / No information

Risk of bias assessment

Responses underlined in green are potential markers for low risk of bias, and responses in red are potential markers for a risk of bias. Where questions relate only to sign posts to other questions, no formatting is used.

Signalling questions	Description	Response options

Bias due to confounding		
1.1 Is there potential for confounding of the effect of intervention in this study? **If N/PN to 1.1:** the study can be considered to be at low risk of bias due to confounding and no further signalling questions need be considered	• Coach's subjective assessment of players' overall performance level → channelling bias, allocation bias • Players' Lifestyle factors (sleep, fatigue, stress, smoking, diet, activity levels) • Players' characteristics (age, body composition, baseline fitness level) • Talent (inherent skill level)	Y / PY / PN / N
If Y/PY to 1.1: determine whether there is a need to assess time-varying confounding:		
1.2. Was the analysis based on splitting participants' follow up time according to intervention received? **If N/PN**, answer questions relating to baseline confounding (1.4 to 1.6) **If Y/PY**, go to question 1.3.	No follow up; just independent cross-sectional measurements over time.	NA / Y / PY / PN / N / NI
1.3. Were intervention discontinuations or switches likely to be related to factors that are prognostic for the outcome? **If N/PN**, answer questions relating to baseline confounding (1.4 to 1.6) **If Y/PY**, answer questions relating to both baseline and time-varying confounding (1.7 and 1.8)	Switching from one condition to another, i.e., training types, was inherent to the set-up.	NA / Y / PY / PN / N / NI

Questions relating to baseline confounding only		
1.4. Did the authors use an appropriate analysis method that controlled for all the important confounding domains?		NA / Y / PY / PN / N / NI
1.5. **If Y/PY to 1.4**: Were confounding domains that were controlled for measured validly and reliably by the variables available in this study?		NA / Y / PY / PN / N / NI
1.6. Did the authors control for any post-intervention variables that could have been affected by the intervention?		NA / Y / PY / PN / N / NI
Questions relating to baseline and time-varying confounding		
1.7. Did the authors use an appropriate analysis method that controlled for all the important confounding domains and for time-varying confounding?		NA / Y / PY / PN / N / NI

1.8. **If Y/PY to 1.7**: Were confounding domains that were controlled for measured validly and reliably by the variables available in this study?		NA / Y / PY / PN / N / NI
Risk of bias judgement		Low / Moderate / Serious / Critical / NI
Optional: What is the predicted direction of bias due to confounding?		Favours experimental / Favours comparator / Unpredictable

Bias in selection of participants into the study		
2.1. Was selection of participants into the study (or into the analysis) based on participant characteristics observed after the start of intervention? **If N/PN to 2.1:** go to 2.4	All participants assessed at the start of the intervention. Participation of those, to specific training sessions over time is not disclosed. But results are only reported for players free of illness or injury	Y / PY / PN / N / NI
2.2. **If Y/PY to 2.1**: Were the post-intervention variables that influenced selection likely to be associated with intervention?		NA / Y / PY / PN / N / NI
2.3 **If Y/PY to 2.2**: Were the post-intervention variables that influenced selection likely to be influenced by the outcome or a cause of the outcome?		NA / Y / PY / PN / N / NI
2.4. Do start of follow-up and start of intervention coincide for most participants?		Y / PY / PN / N / NI
2.5. **If Y/PY to 2.2 and 2.3, or N/PN to 2.4**: Were adjustment techniques used that are likely to correct for the presence of selection biases?		NA / Y / PY / PN / N / NI
Risk of bias judgement		Low / Moderate / Serious / Critical / NI
Optional: What is the predicted direction of bias due to selection of participants into the study?		Favours experimental / Favours comparator / Towards null /Away from null / Unpredictable

Bias in classification of interventions		
3.1 Were intervention groups clearly defined?	One team, 53 players. Did all of them participate in all training types? Were there players without reported data?	Y / PY / PN / N / NI

3.2 Was the information used to define intervention groups recorded at the start of the intervention?		Y / PY / PN / N / NI
3.3 Could classification of intervention status have been affected by knowledge of the outcome or risk of the outcome?	It is reasonable to assume that professional players had to partake in any and all training sessions as scheduled. But it is also conceivable some players might have missed some sessions for because of perception of potential outcome.	Y / PY / PN / N / NI
Risk of bias judgement	It is however not reported explicitly if, over time all 53 players effectively took part in all recorded sessions.	Low / Moderate / Serious / Critical / NI
Optional: What is the predicted direction of bias due to classification of interventions?		Favours experimental / Favours comparator / Towards null /Away from null / Unpredictable

Bias due to deviations from intended interventions		
If your aim for this study is to assess the effect of assignment to intervention, answer questions 4.1 and 4.2		
4.1. Were there deviations from the intended intervention beyond what would be expected in usual practice?		Y / PY / PN / N / NI
4.2. **If Y/PY to 4.1**: Were these deviations from intended intervention unbalanced between groups *and* likely to have affected the outcome?		NA / Y / PY / PN / N / NI
If your aim for this study is to assess the effect of starting and adhering to intervention, answer questions 4.3 to 4.6		
4.3. Were important co-interventions balanced across intervention groups?	Most co-intervention factors are best-case real world. There might be a possible effect of longer training times (fatigue accumulation) in some condition.	Y / PY / PN / N / NI
4.4. Was the intervention implemented successfully for most participants?		Y / PY / PN / N / NI
4.5. Did study participants adhere to the assigned intervention regimen?	Professional players. Intervention regimen = training sessions. No drop-outs reported.	Y / PY / PN / N / NI
4.6. **If N/PN to 4.3, 4.4 or 4.5**: Was an appropriate analysis used to estimate the effect of starting and adhering to the intervention?		NA / Y / PY / PN / N / NI
Risk of bias judgement		Low / Moderate / Serious / Critical / NI
Optional: What is the predicted direction of bias due to deviations from the intended interventions?		Favours experimental / Favours comparator / Towards null /Away from null / Unpredictable

Bias due to missing data		
5.1 Were outcome data available for all, or nearly all, participants?		Y / PY / PN / N / NI
5.2 Were participants excluded due to missing data on intervention status?	Unlikely, as intervention status = participation to training session (=equal for all participants)	Y / PY / PN / N / NI
5.3 Were participants excluded due to missing data on other variables needed for the analysis?		Y / PY / PN / N / NI
5.4 **If PN/N to 5.1, or Y/PY to 5.2 or 5.3**: Are the proportion of participants and reasons for missing data similar across interventions?		NA / Y / PY / PN / N / NI
5.5 **If PN/N to 5.1, or Y/PY to 5.2 or 5.3**: Is there evidence that results were robust to the presence of missing data?		NA / Y / PY / PN / N / NI
Risk of bias judgement	Conscious exclusion of data from injured or ill participants	Low / Moderate / Serious / Critical / NI
Optional: What is the predicted direction of bias due to missing data?		Favours experimental / Favours comparator / Towards null /Away from null / Unpredictable

Bias in measurement of outcomes		
6.1 Could the outcome measure have been influenced by knowledge of the intervention received?		Y / PY / PN / N / NI
6.2 Were outcome assessors aware of the intervention received by study participants?	Inherent to the research. Automised measurements, limited influenceability.	Y / PY / PN / N / NI
6.3 Were the methods of outcome assessment comparable across intervention groups?		Y / PY / PN / N / NI
6.4 Were any systematic errors in measurement of the outcome related to intervention received?	GPS sampling at 5Hz. Some sources were provided as argumentation. However, the literature suggests >5Hz to be acceptable for HIIT team sports with COD. Ideally, 10 Hz. However, this was equal for all participants. Therefore a (systematic or random) non-differential measurement error, affecting precision without causing bias.	Y / PY / PN / N / NI
Risk of bias judgement		Low / Moderate / Serious / Critical / NI
Optional: What is the predicted direction of bias due to measurement of outcomes?		Favours experimental / Favours comparator / Towards null /Away from null / Unpredictable

Bias in selection of the reported result		
Is the reported effect estimate likely to be selected, on the basis of the results, from... 7.1. ... multiple outcome *measurements* within the outcome domain?		Y / PY / PN / N / NI
7.2 ... multiple *analyses* of the intervention-outcome relationship?		Y / PY / PN / N / NI
7.3 ... different *subgroups*?		Y / PY / PN / N / NI
Risk of bias judgement		Low / Moderate / Serious / Critical / NI
Optional: What is the predicted direction of bias due to selection of the reported result?		Favours experimental / Favours comparator / Towards null /Away from null / Unpredictable

Overall bias		
Risk of bias judgement		Low / Moderate / Serious / Critical / NI
Optional: What is the overall predicted direction of bias for this outcome?		Favours experimental / Favours comparator / Towards null /Away from null / Unpredictable

ROBINS-I tool (Stage II): For each study: "How am I going, Coach?" – The effect of augmented feedback during small-sided games on locomotor, physiological, and perceptual responses (Weakley at al. (2019))

Specify a target randomized trial specific to the study

Design	Individually randomized / Cluster randomized / Matched (e.g. cross-over)
Participants	Professional male university level rugby union players
Experimental intervention	The effect of verbal gps-based augmented feedback between small-sided game bouts, on locomotor, physiological, and perceptual responses
Comparator	No-feedback condition

Is your aim for this study…?

☐ to assess the effect of *assignment to* intervention
☐ to assess the effect of *starting and adhering to* intervention

Specify the outcome

Specify which outcome is being assessed for risk of bias (typically from among those earmarked for the Summary of Findings table). Specify whether this is a proposed benefit or harm of intervention.

Benefits: kinematic variables, physiological variables, perceptual variables

Specify the numerical result being assessed

In case of multiple alternative analyses being presented, specify the numeric result (e.g. RR = 1.52 (95% CI 0.83 to 2.77) and/or a reference (e.g. to a table, figure or paragraph) that uniquely defines the result being assessed.

For GPS, HR, dRPE (leg and breathlessness) outcome: Cohen's *d* ES= <0.2 (trivial), 0.20 - 0.59 (small), 0.60 - 1.19 (moderate), 1.20 - 1.99 (large), >2.0 (very large) ± 90% CI; smallest worthwhile change (SWC) = 0.2 with probability of effect > SWC: 25-74.9% = possible, 75-94.9% = likely, 95-99.4 = very likely; ≥ 99.5 = almost certainly.

Preliminary consideration of confounders

Complete a row for each important confounding domain (i) listed in the review protocol; and (ii) relevant to the setting of this particular study, or which the study authors identified as potentially important.

"Important" confounding domains are those for which, in the context of this study, adjustment is expected to lead to a clinically important change in the estimated effect of the intervention. "Validity" refers to whether the confounding variable or variables fully measure the domain, while "reliability" refers to the precision of the measurement (more measurement error means less reliability).

(i) Confounding domains listed in the review protocol				
Confounding domain	Measured variable(s)	Is there evidence that controlling for this variable was unnecessary?*	Is the confounding domain measured validly and reliably by this variable (or these variables)?	OPTIONAL: Is failure to adjust for this variable (alone) expected to favour the experimental intervention or the comparator?
Coach's subjective assessment of players' overall performance level → channeling bias, allocation bias	Randomisation Or identical exposure per player to (all) SSG forms	Yes. Reverse counterbalanced experimental design with position- matched teams in very controlled setting.	Yes / No / No information	Favour experimental / Favour comparator / No information
Overlapping roles (investigator- coach) (= Conflict of Interest) → inclusive bias (due to convenience sampling), observer bias, performance bias, reporting bias	Concealment of allocation to SSGs, Randomisation, Identical exposure per player to SSGs, Or statement of neutrality	Yes. No declaration of conflict of interest. "Two visits per week occurred on the same days" could infer alliance. No mention of coaching staff. But (quasi)-randomised, well- balanced design and methodology with identical exposure per player.	Yes / No / No information	Favour experimental / Favour comparator / No information
Players' Lifestyle factors (sleep, fatigue, stress, smoking, diet, activity levels)	Randomisation Or equal exposure per player to SSGs	Yes. No apparent randomisation with sampling for study. But reverse counterbalanced experimental design with position- matched teams and very controlled setting.	Yes / No / No information	Favour experimental / Favour comparator / No information
Players' characteristics (age, body composition, baseline fitness level)	Clear measurement of these characteristics at baseline, Randomisation, Matching,	Yes. Characteristic reported. Sprint and fitness tested. Positions	Yes / No / No information	Favour experimental / Favour comparator / No information

	Or equal exposure per player to SSGs	matched. Experimental design balanced and standardised.		
Talent (inherent skill level)	Randomisation, Objective skill test, Or equal exposure per player to SSGs	Yes. Reverse counterbalanced experimental design with position- matched teams, and equal exposure, in very controlled setting.	Yes / No / No information	Favour experimental / Favour comparator / No information
Playing position (e.g. Backs vs. forwards)	Randomisation or Matched and cross-over design	Yes. Sprint and fitness tested Reverse counterbalanced experimental design with position- matched teams, and equal exposure, in very controlled setting.	Yes / No / No information	Favour experimental / Favour comparator / No information

(ii) Additional confounding domains relevant to the setting of this particular study, or which the study authors identified as important				
Confounding domain	Measured variable(s)	Is there evidence that controlling for this variable was unnecessary?*	Is the confounding domain measured validly and reliably by this variable (or these variables)?	OPTIONAL: Is failure to adjust for this variable (alone) expected to favour the experimental intervention or the comparator?
			Yes / No / No information	Favour experimental / Favour comparator / No information

* In the context of a particular study, variables can be demonstrated not to be confounders and so not included in the analysis: (a) if they are not predictive of the outcome; (b) if they are not predictive of intervention; or (c) because adjustment makes no or minimal difference to the estimated effect of the primary parameter. Note that "no statistically significant association" is not the same as "not predictive".

Preliminary consideration of co-interventions

Complete a row for each important co-intervention (i) listed in the review protocol; and (ii) relevant to the setting of this particular study, or which the study authors identified as important.

> "Important" co-interventions are those for which, in the context of this study, adjustment is expected to lead to a clinically important change in the estimated effect of the intervention.

(i) Co-interventions listed in the review protocol		
Co-intervention	Is there evidence that controlling for this co-intervention was unnecessary (e.g. because it was not administered)?	Is presence of this co-intervention likely to favour outcomes in the experimental intervention or the comparator
TRAINING STRUCTURE • Non-conditioning training • Timing of conditioning training standardized (on weekly and daily level) for all participants? • Timing within training standardized (groups receive condition at the same time within training?) • Training content (activities) standardized (warm-up effect, fatigue effect)?	Yes. Reverse counterbalanced experimental design with position- matched teams in very controlled setting; pre-fitness testing (48h) buffer, standardised warm-up, rules, opposition, training timing, inter-game timing (20 mins), inter-session timing (48hrs), referee. No information regarding independent rugby training. But well-balanced design.	Favour experimental / Favour comparator / No information
PRE- TRAINING PREPARATION & NUTRITION Club meals, caffeine, massage, foam rolling,… needs to be equal for groups. IF any.	Yes. Was not reported controlled for. But well-balanced design.	Favour experimental / Favour comparator / No information

(ii) Additional co-interventions relevant to the setting of this particular study, or which the study authors identified as important		
Co-intervention	Is there evidence that controlling for this co-intervention was unnecessary (e.g. because it was not administered)?	Is presence of this co-intervention likely to favour outcomes in the experimental intervention or the comparator
		Favour experimental / Favour comparator / No information

Risk of bias assessment

Responses underlined in green are potential markers for low risk of bias, and responses in red are potential markers for a risk of bias. Where questions relate only to sign posts to other questions, no formatting is used.

Signalling questions	Description	Response options
Bias due to confounding		
1.1 Is there potential for confounding of the effect of intervention in this study? **If N/PN to 1.1:** the study can be considered to be at low risk of bias due to confounding and no further signalling questions need be considered	• Overlapping roles (investigator- coach): no declaration of (no) conflict of Interest = suboptimal. No mention of coaching staff leaves room for interpretation. But good design and assignment to teams/conditions was well-balanced. Therefore, biases due to conflicts of interests or convenience sampling (to obtain pool of participants), are somewhat mitigated.	Y / PY / PN / N
If Y/PY to 1.1: determine whether there is a need to assess time-varying confounding:		
1.2. Was the analysis based on splitting participants' follow up time according to intervention received? **If N/PN**, answer questions relating to baseline confounding (1.4 to 1.6) **If Y/PY**, go to question 1.3.		NA / Y / PY / PN / N / NI
1.3. Were intervention discontinuations or switches likely to be related to factors that are prognostic for the outcome? **If N/PN**, answer questions relating to baseline confounding (1.4 to 1.6) **If Y/PY**, answer questions relating to both baseline and time-varying confounding (1.7 and 1.8)		NA / Y / PY / PN / N / NI

Questions relating to baseline confounding only		
1.4. Did the authors use an appropriate analysis method that controlled for all the important confounding domains?		NA / Y / PY / PN / N / NI
1.5. **If Y/PY to 1.4**: Were confounding domains that were controlled for measured validly and reliably by the variables available in this study?		NA / Y / PY / PN / N / NI

1.6. Did the authors control for any post-intervention variables that could have been affected by the intervention?		NA / Y / PY / PN / N / NI
Questions relating to baseline and time-varying confounding		
1.7. Did the authors use an appropriate analysis method that controlled for all the important confounding domains and for time-varying confounding?		NA / Y / PY / PN / N / NI
1.8. **If Y/PY to 1.7**: Were confounding domains that were controlled for measured validly and reliably by the variables available in this study?		NA / Y / PY / PN / N / NI
Risk of bias judgement	Not 100% randomised. But well-balanced, well-controlled real-life design. Possibility of unmentioned affiliation to participants.	Low / Moderate / Serious / Critical / NI
Optional: What is the predicted direction of bias due to confounding?		Favours experimental / Favours comparator / Unpredictable

Bias in selection of participants into the study		
2.1. Was selection of participants into the study (or into the analysis) based on participant characteristics observed after the start of intervention? **If N/PN to 2.1:** go to 2.4	Allocation to teams = position matched at start of intervention. No information concerning participation into study (convenience sampling, purposive sampling?). But players' characteristics obtained pre-allocation to conditions.	Y / PY / PN / N / NI
2.2. **If Y/PY to 2.1**: Were the post-intervention variables that influenced selection likely to be associated with intervention?		NA / Y / PY / PN / N / NI
2.3 **If Y/PY to 2.2**: Were the post-intervention variables that influenced selection likely to be influenced by the outcome or a cause of the outcome?		NA / Y / PY / PN / N / NI
2.4. Do start of follow-up and start of intervention coincide for most participants?	Only Start for both groups, no follow-up. But experiment is well-timed and structured.	Y / PY / PN / N / NI
2.5. **If Y/PY to 2.2 and 2.3, or N/PN to 2.4**: Were adjustment techniques used that are likely to correct for the presence of selection biases?		NA / Y / PY / PN / N / NI
Risk of bias judgement	Eligible participants were included into study, seemingly. But likely through purposive/convenience sampling. Start of intervention coincided.	Low / Moderate / Serious / Critical / NI
Optional: What is the predicted direction of bias due to selection of participants into the study?		Favours experimental / Favours comparator / Towards null /Away from null / Unpredictable

Bias in classification of interventions		
3.1 Were intervention groups clearly defined?		Y / PY / PN / N / NI
3.2 Was the information used to define intervention groups recorded at the start of the intervention?		Y / PY / PN / N / NI
3.3 Could classification of intervention status have been affected by knowledge of the outcome or risk of the outcome?		Y / PY / PN / N / NI
Risk of bias judgement		Low / Moderate / Serious / Critical / NI
Optional: What is the predicted direction of bias due to classification of interventions?		Favours experimental / Favours comparator / Towards null /Away from null / Unpredictable

Bias due to deviations from intended interventions		
If your aim for this study is to assess the effect of assignment to intervention, answer questions 4.1 and 4.2		
4.1. Were there deviations from the intended intervention beyond what would be expected in usual practice?		Y / PY / PN / N / NI
4.2. **If Y/PY to 4.1**: Were these deviations from intended intervention unbalanced between groups *and* likely to have affected the outcome?		NA / Y / PY / PN / N / NI
If your aim for this study is to assess the effect of starting and adhering to intervention, answer questions 4.3 to 4.6		
4.3. Were important co-interventions balanced across intervention groups?		Y / PY / PN / N / NI
4.4. Was the intervention implemented successfully for most participants?		Y / PY / PN / N / NI
4.5. Did study participants adhere to the assigned intervention regimen?		Y / PY / PN / N / NI
4.6. **If N/PN to 4.3, 4.4 or 4.5**: Was an appropriate analysis used to estimate the effect of starting and adhering to the intervention?		NA / Y / PY / PN / N / NI
Risk of bias judgement		Low / Moderate / Serious / Critical / NI

Optional: What is the predicted direction of bias due to deviations from the intended interventions?		Favours experimental / Favours comparator / Towards null /Away from null / Unpredictable

Bias due to missing data		
5.1 Were outcome data available for all, or nearly all, participants?		Y / PY / PN / N / NI
5.2 Were participants excluded due to missing data on intervention status?	Unlikely, considering n= 20 and 4 teams of 5 players were needed.	Y / PY / PN / N / NI
5.3 Were participants excluded due to missing data on other variables needed for the analysis?	Unlikely, considering n= 20 and 4 teams of 5 players were needed.	Y / PY / PN / N / NI
5.4 **If PN/N to 5.1, or Y/PY to 5.2 or 5.3**: Are the proportion of participants and reasons for missing data similar across interventions?		NA / Y / PY / PN / N / NI
5.5 **If PN/N to 5.1, or Y/PY to 5.2 or 5.3**: Is there evidence that results were robust to the presence of missing data?		NA / Y / PY / PN / N / NI
Risk of bias judgement		Low / Moderate / Serious / Critical / NI
Optional: What is the predicted direction of bias due to missing data?		Favours experimental / Favours comparator / Towards null /Away from null / Unpredictable
Bias in measurement of outcomes		
6.1 Could the outcome measure have been influenced by knowledge of the intervention received?		Y / PY / PN / N / NI
6.2 Were outcome assessors aware of the intervention received by study participants?	Unclear if standardised feedback providing, i.e. "sport scientist", was also outcome assessor. But assessment methods were validated, mostly electronically automated measurements. Influence on dRPE (suggestiveness)? Depending on practical executing by assessor, and actual (original, validated, non-coloured) scale used (no info).	Y / PY / PN / N / NI
6.3 Were the methods of outcome assessment comparable across intervention groups?		Y / PY / PN / N / NI
6.4 Were any systematic errors in measurement of the outcome related to intervention received?	GPS 10Hz is ideal. Nevertheless, equal for all participants. Therefore a (systematic or random) non-differential measurement error, affecting precision without causing bias.	Y / PY / PN / N / NI
Risk of bias judgement		Low / Moderate / Serious / Critical / NI

Optional: What is the predicted direction of bias due to measurement of outcomes?		Favours experimental / Favours comparator / Towards null /Away from null / Unpredictable

Bias in selection of the reported result		
Is the reported effect estimate likely to be selected, on the basis of the results, from... 7.1. ... multiple outcome *measurements* within the outcome domain?	Same ES estimates within outcome domains (i.e. kinematic, physiological, perceptual)	Y / PY / PN / N / NI
7.2 ... multiple *analyses* of the intervention-outcome relationship?		Y / PY / PN / N / NI
7.3 ... different *subgroups*?		Y / PY / PN / N / NI
Risk of bias judgement		Low / Moderate / Serious / Critical / NI
Optional: What is the predicted direction of bias due to selection of the reported result?		Favours experimental / Favours comparator / Towards null /Away from null / Unpredictable

Overall bias		
Risk of bias judgement		Low / Moderate / Serious / Critical / NI
Optional: What is the overall predicted direction of bias for this outcome?		Favours experimental / Favours comparator / Towards null /Away from null / Unpredictable

Rater 2 - The Risk Of Bias In Non-randomized Studies – of Interventions (ROBINS-I) adapted assessment tool

Participants: Male Rugby Union players

Experimental intervention: APPLICATION OF SMALL-SIDED GAMES

Comparator: TRADITIONAL RUGBY TRAINING

Outcomes: TRAINING RESPONSES (CHRONIC AND ACUTE) [“effects on physiological, kinematic, physical, technical, tactical variables”]

Confounders

- Coach’s subjective assessment of players’ overall performance level
- Overlapping roles (investigator- coach) (Conflict of Interest)
- Players’ Lifestyle factors (sleep, fatigue, stress, smoking, diet, activity levels)
- Players’ characteristics (age, body composition, baseline fitness level)
- Talent (inherent skill level)
- Playing position (e.g., Backs vs. forwards)"

Co-Interventions

TRAINING STRUCTURE

- Timing of training standardized (on weekly and daily level)?
- Timing within training standardized (groups receive condition at the same time within training?)
- Training content (activities) standardized (warm-up effect, fatigue effect)?

PRE- TRAINING PREPARATION & NUTRITION

Club meals, caffeine, massage, foam rolling (needs to be equal for groups. IF any).

Risk of Bias Domains (1-7)	**Gamble (2004)**	**Kennett, Kempton, & Coutts (2012)**				**Vaz et al. (2012)**			**Vaz, Figueira & Gonçalves (2015)**		**Vaz et al. (2016)**		**Tee, Lambert & Coopoo (2016)**	**Weakley et al. (2019)**		
Outcome Variable	Heart Rate	Heart rate	GPS	Lactate	RPE	Heart Rate	GPS	Skill (video)	Heart Rate	GPS	Heart Rate	GPS	GPS	GPS	Heart Rate	RPE
Bias due to confounding																
1.1 Is there potential for confounding of the effect of intervention in this study?	Y - investigator-coach	N	N	N	N	Y	Y	Y	PN - **Randomised** session order, age groups, lifestyle, coach-investigator		PY - not randomised, group allocations, subjective, backs/forwards?		PY - Subjective, lifestyle, talent, allocation,	PN - Counterbalanced, overlapping roles		
1.2 Was the analysis based on splitting participants' follow up time according to intervention received? If N/PN, answer questions relating to baseline confounding (1.4 to 1.6) If Y/PY, go to question 1.3.	N - only 1 group.	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA		

1.3 Were intervention discontinuations or switches likely to be related to factors that are prognostic for the outcome? If N/PN, answer questions relating to baseline confounding (1.4 to 1.6) If Y/PY, answer questions relating to both baseline and time-varying confounding (1.7 and 1.8)		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	N	NA
Questions relating to baseline confounding only														
1.4 Did the authors use an appropriate analysis method that controlled for all the important confounding domains?	PN	NA	NA	NA	NA	PN	PN	PN	PY	PY- 5 hz	PN	PN	N	PY
1.5 If Y/PY to 1.4: Were confounding		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	Y

domains that were controlled for measured validly and reliably by the variables available in this study?														
1.6 Did the authors control for any post-intervention variables that could have been affected by the intervention?	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Questions relating to baseline and time-varying confounding													NA	
1.7 Did the authors use an appropriate analysis method that controlled for all the important confounding domains and for time-varying confounding?	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	PN	PN	NA	NA
1.8 If Y/PY to 1.7: Were confounding domains that were controlled for measured validly and		NA	NA	NA	NA	NA	NA	NA	NA	NA	PY	PY	NA	NA

reliably by the variables available in this study?																
<u>Risk of bias judgement (L/M/S/C/NI).</u>	**SERIOUS-CRITICAL**	**LOW**				**CRITICAL**	**CRITICAL**	**CRITICAL**	**LOW**	**LOW**	**CRIIC AL**	**CRITICAL**	**CRITICAL**	**MODERATE**		
What is the predicted direction of bias due to confounding? Favours experimental / Favours comparator / Unpredictable	1 group. No control. Coach-investigator	Notes:				Coach-investigator. Lifestyle. Playing position. Coaches subjective assessment of skill.										

Bias in participant selection	**Gamble (2004)**	**Kennett, Kempton, & Coutts (2012)**				**Vaz et al. (2012)**	**Vaz, Figueira & Gonçalves (2015)**		**Vaz et al. (2016)**		**Tee, Lambert & Coopoo (2016)**	**Weakley et al. (2019)**
2.1 Was selection of participants into the study (or into the analysis) based on participant characteristics observed after the start of intervention? If N/PN to 2.1: go to 2.4	N - only 1 group.	N - Subjects matched and randomised.				PN - Split into experienced vs novice.	Y - cluster analysis pooled grp when given diff. sessions	Y - cluster analysis pooled when given diff. sessions	N	N	N	N- Teams matched, counterbalanced.
2.2 If Y/PY to 2.1: Were the post-intervention variables that influenced selection likely to be associated with intervention?		NA	NA	NA	NA	NA	PN	PN	N	N	N	

2.3 If Y/PY to 2.2: Were the post-intervention variables that influenced selection likely to be influenced by the outcome or a cause of the outcome?		NA	NA	NA	NA	NA	PN	PN				
2.4 . Do start of follow-up and start of intervention coincide for most participants?	Y					No follow-up	No follow-up	No follow-up	No follow-up		Y	Y
2.5 If Y/PY to 2.2 and 2.3, or N/PN to 2.4: Were adjustment techniques used that are likely to correct for the presence of selection biases?		NA	NA	NA	NA	NA					NA	NA
<u>Risk of bias judgement (L/M/S/C/NI).</u>	**LOW**	**LOW**				**MODERATE**	**SERIOUS**	**SERIOUS**	LOW	LOW	**LOW**	**LOW**
What is the predicted direction of bias due to selection of participants into the study? Favours experimental / Favours comparator / Towards null /Away from null / Unpredictable						Missing detail on how participant selection completed						
Bias in classification of interventions							U16 v U18, Cluster performance comparison		Within group comparison of SSG formats		1 Group - cross-over	4 Teams matched, counterbalanced.
3.1 Were intervention groups clearly defined?	Y	Y - 1 group acute, randomised, cross-over.				PY - Exp vs Novice.	PN	PN	Y	Y	Y	Y
3.2 Was the information used to define intervention groups recorded at the start of the intervention?	Y	Y				Y	Y	Y	Y	Y	Y	Y
3.3 Could **classification** of intervention status have been	N - only 1 group.	N - only 1 group.				PY - Subjective skill /Obj. >	N	N	N	N	PN	**N**

affected by knowledge of the outcome or risk of the outcome?			5yrs rugby allocation					
<u>Risk of bias judgement (L/M/S/C/NI).</u>	**LOW**	**LOW**	**MODERATE**	**MODERATE-SERIOUS**	LOW	LOW	**LOW**	**LOW**
What is the predicted direction of bias due to classification of interventions? Favours experimental / Favours comparator / Towards null /Away from null / Unpredictable	.	.						

Bias due to deviations from intended interventions	**Gamble (2004)**	**Kennett, Kempton, & Coutts (2012)**	**Vaz et al. (2012)**	**Vaz, Figueira & Gonçalves (2015)**	**Vaz et al. (2016)**	**Tee, Lambert & Coopoo (2016)**	**Weakley et al. (2019)**
If your aim for this study is to assess the ***effect of assignment*** to			Effect of assignment to group: Novice and Experienced. SSG allocation not specified or randomised.	U16 and U18 given different SSG/training. Not standardised across groups.		Cross-over	Cross-over feedback vs no feedback

intervention, answer questions 4.1 and 4.2							
4.1 Were there deviations from the intended intervention beyond what would be expected in usual practice?							
4.2 . If Y/PY to 4.1: Were these deviations from intended intervention unbalanced between groups and likely to have affected the outcome?							
If your aim for this study is to assess the effect of starting and adhering to intervention, answer questions 4.3 to 4.6	One Group only.						
4.3 Were important co-interventions balanced	PY	Y	PN - Rugby and other training not specified.	N - In-season, different age groups, different interventions	PN - In-season, order not randomised.	PN - pre-season, In-	Y - acute, standardised, counterbalanced

across intervention groups?						season, 25 months, diminis hing returns	
4.4 Was the intervention implemented successfully for most participants?	Y	Y	Y - No drop-out reported	Y- No dropouts	Y- No dropouts	PY	Y
4.5 Did study participants adhere to the assigned intervention regimen?	PY	Y	Y	Y	Y	Y	Y
4.6 If N/PN to 4.3, 4.4 or 4.5: Was an appropriate analysis used to estimate the effect of starting and adhering to the intervention?	[redacted]					NA	Y
Risk of bias judgement (L/M/S/C/NI).	**LOW**	**LOW**	**LOW**	**CRITICAL**	**MODERATE**	**SERIO US**	**LOW**
What is the predicted direction of bias due to deviations from the intended interventions?	Assess effect of SSG on HR recover y						

Bias due to missing data	**Gamble (2004)**	**Kennett, Kempton, & Coutts (2012)**	**Vaz et al. (2012)**			**Vaz, Figueira & Gonçalves (2015)**	**Vaz et al. (2016)**	**Tee, Lambert & Coopoo (2016)**	**Weakley et al. (2019)**
5.1 Were outcome data available for all, or nearly all, participants?	Y - (34/35)	Y - Mean +/-SD	Y	Y	Y	Y	Y	NI	Y
5.2 Were participants excluded due to missing data on intervention status?	Y	N	N			N	N	PN	N
5.3 Were participants excluded due to missing data on other variables needed for the analysis?	N	N	N			N	N	NI	N
5.4 **If** **PN/N** **to 5.1, or** **Y/PY** **to 5.2 or 5.3**: Are the proportion of participants and reasons for missing data similar across interventions?								NA	

5.5 **If PN/N to 5.1, or Y/PY to 5.2 or 5.3**: Is there evidence that results were robust to the presence of missing data?	[redacted]												NA	[redacted]		
<u>Risk of bias judgement (L/M/S/C/NI).</u>	**LOW**	**LOW**				**LOW**			**LOW**		**LOW**		**LOW**	**LOW**		
What is the predicted direction of bias due to missing data?	1 injured athlete															
Bias in measurement of outcomes	**Gamble (2004)**	**Kennett, Kempton, & Coutts (2012)**				**Vaz et al. (2012)**			**Vaz, Figueira & Gonçalves (2015)**		**Vaz et al. (2016)**		**Tee, Lambert & Coopoo (2016)**	**Weakley et al. (2019)**		
OUTCOME VARIABLE	**Heart Rate**	**Heart rate**	**GPS**	**Lactate**	**RPE**	**Heart Rate**	**GPS**	**Skill (video)**	**Heart Rate**	**GPS**	**HR**	**GPS**	**GPS**	**GPS**	**HR**	**RPE**
6.1 Could the outcome measure have been influenced by	N	N-HR	N-GPS	N-Lactate	N - RPE (Borg)	N-HR	N-GPS	PN-Skill	N-HR	N-GPS	PN	PN	N	N-GPS	N-HR	N-RPE

knowledge of the intervention received?																
6.2 Were outcome assessors aware of the intervention received by study participants?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
6.3 Were the methods of outcome assessment comparable across intervention groups?		Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
6.4 Were any systematic errors in measurement of the outcome <u>related to intervention received</u>?	PN - HR values altered wkly.	N	N - 1 Hz system	N - calibrated	N	N	N-5 hz	PN - video	N	N - 5 Hz	PN	PN	PN - 5 Hz	N - 10 HZ	N-Polar	N-CR100 scale
<u>Risk of bias judgement (L/M/S/C/NI).</u>	**LOW**	**LOW**	**LOW**	**LOW**	**LOW**	**LOW**	**LOW**	**LOW**	**LOW**	**LOW**	**LOW**	**LOW**	**LOW**	**LOW**	**LOW**	**LOW**
What is predicted direction of bias due to measurement outcome related to intervention	HRMax and HRR relative outputs adjusted weekly															

	, that would be influenced by training.															
Bias in selection of reported results	**Gamble (2004)**	**Kennett, Kempton, & Coutts (2012)**				**Vaz et al. (2012)**			**Vaz, Figueira & Gonçalves (2015)**		**Vaz et al. (2016)**		**Tee, Lambert & Coopoo (2016)**	**Weakley et al. (2019)**		
Is the reported effect estimate likely to be selected, on the basis of the results, from…									Performance predictor model, cluster model post-intervention.							
7.1 multiple outcome measurements within outcome domain.	N	N	PN	N	N	N	PN	N	N	N	N	N	N	N	N	N
7.2 multiple analyses of the intervention outcome relationship	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N

7.3 different subgroups?	N	N	N	N	N	N	N	PN	PN	PN	N	N	N	N	N	N
Risk of bias judgement (L/M/S/C/NI).	**LOW**	**LOW**	**LOW**	**LOW**	**LOW**	**LOW**	**LOW**	**LOW**	**LOW**	**LOW**	**LOW**	**LOW**	**LOW**	**LOW**	**LOW**	**LOW**
What is the predicted direction of bias due to missing data?																
OVERALL Risk of Bias (Low / Moderate / Serious / Critical / NI)	**SERIOUS**	**LOW**	**CRITICAL**	**LOW**	**LOW**	**CRITICAL**	**CRITICAL**	**CRITICAL**	**CRITICAL**	**CRITICAL**	**CRITICAL**	**CRITICAL**	**CRITICAL**	**LOW**	**LOW**	**LOW**
What is the overall predicted direction of bias for this outcome?																

Appendix 7: Study quality assessment tools

10-point quality assessment tool (Brughelli et al., 2008)	**16-item risk-of-bias quality form (Sarmento et al., 2008)**
1. Inclusion criteria were clearly stated; 2. Subjects were randomly allocated to groups; 3. Intervention was clearly defined; 4. Groups were tested for similarity at baseline; 5. Use of a control group; 6. Outcome variables were clearly defined; 7. Assessments were practically useful; 8. Duration of intervention practically useful; 9. Between-group statistical analysis appropriate; 10. Point measures of variability.	1. Was the study purpose stated clearly? 2. Was relevant background literature reviewed? 3. Was the design appropriate for the research question? 4. Was the sample described in detail? 5. Was sample size justified? 6. Was informed consent obtained? (if not described, assume No) 7. Were the outcome measures reliable? (if not described, assume No) 8. Were the outcome measures valid? (if not described, assume No) 9. Was method described in detail? 10. Were results reported in terms of statistical significance? 11. Were the analysis methods appropriate? 12. Was importance for the practice reported? 13. Were any dropouts reported? 14. Were conclusions appropriate given the study methods? 15. Are there any implications for practice given the results of the study? 16. Were limitations of the study acknowledged and described by the authors?

Appendix 8: Survey workflow process

SURVEY DESIGN

developmental process as described by Portney and Watkins (2009)[486]:

1. **Delineation of the research question**
    a. **Guiding questions**
    b. **Hypotheses**
    c. **Questionnaire outline**
2. **Review of existing instruments**
3. **Design of the instrument**
4. **Preliminary drafts**
5. **Pilot testing and revisions**
6. **Selecting a sample**
7. **Contacting respondents**
    a. **Cover letter**

1.a. Guiding questions

1. How widely spread is the use of SSGs in rugby union training practice?
2. What are SSGs generally used for in rugby union training practice?
3. How frequently are SSGs used in rugby union training practice?
4. Which SSG formats are most popular in rugby union training practice?
5. What specific playing rules are applied to SSGs in rugby union training practice?
6. What are the specific conditioning goals SSGs are used for in rugby union training practice?
7. How long for are SSGs implemented for during rugby union training practice?
8. Is GPS tracking used during rugby union training practice?
9. Is GPS tracking used to track loading in SSGs specifically, in rugby union training practice?
10. Is there a relationship between rugby union coaching characteristics and the interpretation and implementation of SSGs in rugby union training practice?

1.b. Hypotheses

1. SSGs are used on every level in rugby union training practice.
2. SSGs are used for multiple reasons, including match specific conditioning, game skills development and fun experience/ motivation.
3. SSGs are used more frequently with rising playing level.
4. Mid-range SSGs (5v5 – 9v9) are most frequently used.
5. A diverse array of touch rules is most frequently applied to rugby union SSGs.
6. Match specific aerobic conditioning is the main conditioning goal when applying SSGs in rugby union training practice.
7. SSGs are mostly used for a duration of over four minutes, without multiple playing bouts.
8. GPS tracking is mainly used at the higher levels, national and above.
9. GPS tracking for SSG loading is more consequently used on Super Rugby and international-level compared to lower-level rugby union play.
10. Implementation and interpretation of SSGs in rugby union will be dependent of coaching characteristics.

1.c. Questionnaire outline

Cf. Qualtricks software outline[487].

2. Review of existing instruments

Methodological convenience:

- e-questionnaire – maximal dispersion, bigger reach.
- Availability of Qualtrics software[488] (University of Waikato software licence[489])

3. Design of the instrument

Cf. Qualtrics software workflow.

4. Preliminary drafts

Presented for evaluation to:

- Dr. Travis McMaster
- Dr. Martyn Beaven
- Dr. Nic Gill

5. Pilot testing and revisions

Tested by research colleagues/ coaches:

- Rogers T. – Sport science (rugby) researcher – S&C coach
- Sella F. – Sport science (rugby) researcher
- McNeil C. – sport science (rugby) researcher – S&C coach
- Wardell G. – Sport science student - researcher
- Anderson B. – Elite-level rugby union coach

6. Selecting a sample

Sample: Rugby union coaching staff.

Dispersion through

- University of Waikato Adams Centre for High Performance contacts
- Bay of Plenty Rugby Union
- Social media and email contact listing of rugby union coaching staff
- Publicly available national and provincial governing bodies' email addresses
- Publicly available Department of New Zealand Education school mailing list

7. Contacting respondents - Cover letter

Cover letter(s) through Qualtrics software layout:

Dear Sir, Madam

In the context of our **research into rugby union** performance, we are conducting several studies regarding small-sided game play, and its relation to the full game. We have set out to investigate these popular training forms in a multifaceted manner. It is our intention **to add to the body of knowledge, and better rugby training** practice on all playing levels. We believe this research is **very relevant**, **and** the topic **prevalent**. Therefore, we have aimed at **maximising input from all stakeholders**.

We would like to politely ask for your cooperation in maximising the research's impact, by helping in the global exposure and **dispersion of the message below**. We have attempted to spread this message throughout the educational system and rugby circuit but fear it has only had limited exposure. If you are in any way capable of spreading the message below, or have it reach the right people for it, it **would be greatly appreciated**. In this manner, we can aim at getting a clearer view on rugby training and development, to the benefit of all involved.

With the highest regards,

Koen Wintershoven - MSc, B.Ed - PhD Candidate
Te Huataki Waiora School of Health
University of Waikato
Adams Centre for High Performance
52 Miro St, Mount Maunganui 3116, New Zealand
+64 (0)21 0341203

Dear Sir, Madam

Below you can find the link to the E-SURVEY regarding my ongoing PhD research into the APPLICATION OF SMALL AND LARGE-SIDED GAMES TO RUGBY UNION. In this research, all levels of rugby union play are of key importance.

This study will help clarify the actual use of these popular team sport-conditioning forms. As such, it serves an essential purpose to further our understanding and optimise training methods in rugby union. So that all stakeholders can benefit, from school and local level, to international rugby union players.

If you are in any way involved in rugby union training and can spare 10 minutes, it would be great if you could take the survey. Please FEEL FREE TO SHARE the link within the rugby union community.

https://waikato.qualtrics.com/jfe/form/SV_ey2unAbYLWr5TVj

Thank you!

Kind regards,
Ngā mihi,

Koen Wintershoven - MSc, B.Ed - PhD Candidate
Te Huataki Waiora School of Health
University of Waikato
Adams Centre for High Performance
52 Miro St, Mount Maunganui 3116, New Zealand
+64 (0)21 0341203

Appendix 9: Survey content

Information sheet – Consent

THE USE OF SMALL AND LARGE-SIDED GAMES IN RUGBY UNION - SURVEY

AIM

To determine the **current use of small and large-sided games** in rugby union practice across all levels of play.

BACKGROUND

Rugby is an important and highly demanding global team sport. **Training plays a crucial role** in the development, preparation, and safety of players. Small and larger-sided games (SSGs) are therefor used in many sports. The effects of various **SSGs have** nevertheless **not yet been investigated properly in rugby union**.

OVERVIEW

By completing this questionnaire you will provide anonymous **information about your role as training staff** and the use of conditioning games. This should take **10 minutes** approximately. By **submitting** your responses, you will be giving **informed consent** for this information to be used in the research project stated above, to the benefit of rugby players, coaches and the scientific body of knowledge.

POTENTIAL RISKS

There are **no foreseeable risks** involved with the participation in this survey.

WHAT WILL HAPPEN TO THE INFORMATION COLLECTED

This information can be used in function of:

- Research reports;
- Development of an optimised training tool;
- Scientific presentations;
- Education of students and the wider community;

The **data will be treated with the strictest confidentiality**, according to procedures approved by the Human Research Ethics Committee (Health) of the University of Waikato.

DECLARATION TO PARTICIPANTS

If you choose to take part in this study, you understand that:

- Participation is completely **voluntary and anonymous**;
- **No sensitive information** is requested, and you may refuse to answer any question;
- Once survey responses are submitted, identification will not be possible and therefore **withdrawal** of **individual responses nor complete** withdrawal from the study will be **possible**;
- The data might be published, so every effort will be made to ensure **confidentiality and anonymity**.

WHO IS RESPONSIBLE

If you have any questions about the project, please feel free to contact:

Koen Wintershoven, MSc, BEd. (Lead Investigator)
The University of Waikato, Adams Centre for High Performance
52 Miro Street, Mount Maunganui 3116
kw134@students.waikato.ac.nz

Dr. Daniel Travis McMaster (Primary Supervisor)
daniel.mcmaster@waikato.ac.nz

HUMAN RESEARCH ETHICS COMMITTEE

This research project has been approved by the Human Research Ethics Committee (Health) of the University of Waikato under **HREC(Health)2019#15**.

Any questions about the ethical conduct of this research may be addressed to the Secretary of the Committee, email **humanethics@waikato.ac.nz**, postal address, University of Waikato, Te Whare Wananga o Waikato, Private Bag 3105, Hamilton 3240.

E-survey questions

1. Please select your current involvement status in RUGBY UNION coaching.
2. Which term best describes your function?
3. Where have you mainly been active in your role?
4. Which experience category describes your role(s) best?
5. What level matches your current RUGBY UNION activities best?
6. What gender players are you usually involved with?
7. Please select the age category you most often work(ed) with in rugby union.
8. In the context of this study, "small-sided games" (SSGs) and "larger-sided games" (LSGs) refer to any modified version of the full game of rugby (15 v 15), whereby through alteration of design variables like player number, playing area, time, and rules, a specific training outcome is pursued. The games should still be identifiable as rugby-related (rugby ball, contact, basic plays).
9. How often do you use SSGs and LSGs (excl. 15 v 15) for training purposes?
10. What overall purpose(s) describes your use of small-sided games (SSGs) best? Please select up to 3 maximally.
11. Please drag and drop YOUR TOP 5 out of the following SSG FORMATS, by likeliness of use in your training practice (1 = most likely, 5 = least likely).
12. For YOUR TOP 5 SSG FORMATS as stated before, specify the main purpose(s) of use. Please select up to 3 options per SSG format.
13. If only one is allowed, which of the following playing rules would you implement preferentially during SSGs?
14. How many touches would you preferably allow before a turnover in SSGs?
15. If only one is allowed, which of the following passing rules would you implement preferentially during SSGs?
16. Which proportion (%) of the full PITCH DO YOU USE for your SSGs?
17. Please select the SSG RULES YOU IMPLEMENT REGULARLY in your training practice by providing the motivation for use.
18. How long would your average SSG DURATION generally be?
19. How many SSG PLAYING BOUTS would you preferably implement consecutively?
20. How long would your average SSG REST DURATION between playing bouts generally be?
21. I mainly use GPS tracking (select up to 3)
22. In the context of this study, "small-sided games" (SSGs) and "larger-sided games" (LSGs) refer to any modified version of the full game of rugby (15 v 15), whereby through alteration of design variables like player number, playing area, time, and rules, a specific training outcome is pursued. The games should still be identifiable as rugby-related (rugby ball, contact, basic plays). I understand and agree with that definition/would alter that definition to:…
23. Is there ANY ADDITIONAL INFORMATION you would like to add to complement your answers to the questions above?

E-survey format

○ I have read and understood the information

Q1 Please select your current involvement status in RUGBY UNION coaching.

○ Actively coaching

○ Have coached, not currently active

○ Have never coached (Please exit survey, thank you for your interest)

Q3 Which term best describes your function?

○ Head Coach

○ Strength and Conditioning Coach

○ Assistant Coach

○ Team sport scientist

○ Other; please specify ____

Q23 Where have you mainly been active in your role?

- New Zealand
- Australia
- Europe
- Asia
- Africa
- South America
- North America
- Pacific Islands
- Other, please specify ____

Q4 Which experience category describes your role(s) best?

- Less than 1 year
- 1 to 3 years
- 3 to 5 years
- 5 to 10 years
- More than 10 years

Q2 What level matches your current RUGBY UNION activities best?

- ◯ International
- ◯ Professional (e.g., Super Rugby, Pro14)
- ◯ National
- ◯ Local
- ◯ School

Q22 What gender players are you usually involved with?

- ◯ Female
- ◯ Male
- ◯ Both

Q21 Please select the age category you most often work(ed) with in rugby union.

- ☐ U6
- ☐ U8
- ☐ U10
- ☐ U12
- ☐ U14
- ☐ U16
- ☐ U18
- ☐ U21
- ☐ Seniors (21+)

Q29 In the context of this study, "small-sided games" (SSGs) and "larger-sided games" (LSGs) refer to any modified version of the full game of rugby (15 v 15), whereby through alteration of design variables like player number, playing area, time, and rules, a specific training outcome is pursued. The games should still be identifiable as rugby-related (rugby ball, contact, basic plays).

- ○ I understand and agree with that definition
- ○ I understand but would alter that definition to: ________________

Q5 How often do you use SSGs and LSGs (excl. 15 v 15) for training purposes?

- Very often (every training session)
- Regularly (every 2 to 3 training sessions)
- Sometimes (at least once every 5 training sessions)
- Seldom (less than once every 5 training sessions)
- Never

Q6 What overall purpose(s) describes your use of small-sided games (SSGs) best? Please select up to 3 maximally.

- Fun
- Tactical training
- Team building
- Physical conditioning
- Technical skill development
- Other, Please specify ____

Q7 Please drag and drop YOUR TOP 5 out of the following SSG FORMATS, by likeliness of use in your training practice (1 = most likely, 5 = least likely).

1	2	3	4	5
______ 1 v 1	______ 1 v 1	______ 1 v 1	______ 1 v 1	______ 1 v 1
______ 3 v 3	______ 3 v 3	______ 3 v 3	______ 3 v 3	______ 3 v 3
______ 5 v 5	______ 5 v 5	______ 5 v 5	______ 5 v 5	______ 5 v 5
______ 7 v 7	______ 7 v 7	______ 7 v 7	______ 7 v 7	______ 7 v 7
______ 9 v 9	______ 9 v 9	______ 9 v 9	______ 9 v 9	______ 9 v 9
______ 11 v 11	______ 11 v 11	______ 11 v 11	______ 11 v 11	______ 11 v 11
______ 2 v 2	______ 2 v 2	______ 2 v 2	______ 2 v 2	______ 2 v 2
______ 4 v 4	______ 4 v 4	______ 4 v 4	______ 4 v 4	______ 4 v 4
______ 6 v 6	______ 6 v 6	______ 6 v 6	______ 6 v 6	______ 6 v 6
______ 8 v 8	______ 8 v 8	______ 8 v 8	______ 8 v 8	______ 8 v 8
______ 10 v 10	______ 10 v 10	______ 10 v 10	______ 10 v 10	______ 10 v 10

Q14 For YOUR TOP 5 SSG FORMATS as stated before, specify the main purpose(s) of use. Please select up to 3 options per SSG format.

	General aerobic conditioning	VO2max training	Rugby skill development	Repeated sprint training	Specific match conditioning	Recuperation	Lactate threshold training	Other
1 v 1								
2 v 2								
3 v 3								
4 v 4								
5 v 5								
6 v 6								
7 v 7								
8 v 8								
9 v 9								
10 v 10								
11 v 11								

Q8 If only one is allowed, which of the following playing rules would you implement preferentially during SSGs?

- ○ Union rules (tackling allowed)
- ○ Touch rules (no wrapping, no tackling)
  - ○ Wrapping

Q9 How many touches would you preferably allow before a turnover in SSGs?

- ○ 7
- ○ 6
- ○ 5
- ○ 4
- ○ 3
- ○ 2
- ○ 1

Q10 If only one is allowed, which of the following passing rules would you implement preferentially during SSGs?

- ○ Forward passing allowed
- ○ Backwards passing only

Q24 Which proportion (%) of the full PITCH DO YOU USE for your SSGs?

	% OF FULL PITCH 0 10 20 30 40 50 60 70 80 90 100
SSG SMALL PITCH	
SSG MEDIUM PITCH	
SSG LARGE PITCH	

Q20 Please select the SSG RULES YOU IMPLEMENT REGULARLY in your training practice by providing the motivation for use.

	TRAINING GOAL					
	Alter physical intensity	Promote skill development	Tactical awareness	Playing position specificity	Fun	Other

Defender down/up on touch	☐	☐	☐	☐	☐	☐
Defender takes a knee on touch	☐	☐	☐	☐	☐	☐
Defending player drops off	☐	☐	☐	☐	☐	☐
Defender back to mark on touch	☐	☐	☐	☐	☐	☐
Man on man marking	☐	☐	☐	☐	☐	☐
Off side touch	☐	☐	☐	☐	☐	☐
Neutral player(s)	☐	☐	☐	☐	☐	☐
Physical exercise on external cue	☐	☐	☐	☐	☐	☐
Alternative and/or multiple try areas	☐	☐	☐	☐	☐	☐
1 hand touch	☐	☐	☐	☐	☐	☐
2 hand touch	☐	☐	☐	☐	☐	☐
Flag touch	☐	☐	☐	☐	☐	☐
2- player touch	☐	☐	☐	☐	☐	☐
Try scored by passing into try zone	☐	☐	☐	☐	☐	☐
Uneven numbers (teams)	☐	☐	☐	☐	☐	☐
Other, please specify	☐	☐	☐	☐	☐	☐

Q11 How long would your average SSG DURATION generally be?

- ○ Less than 2 minutes
- ○ Between 2 and 4 minutes
- ○ Between 4 and 6 minutes
- ○ Between 6 and 8 minutes
- ○ Between 8 and 10 minutes
- ○ More than 10 minutes

Q12 How many SSG PLAYING BOUTS would you preferably implement consecutively?

- ○ 1
- ○ 2
- ○ 3
- ○ 4
- ○ 5 or more

Q13 How long would your average SSG REST DURATION between playing bouts generally be?

- More than 10 minutes
- Between 8 and 10 minutes
- Between 6 and 8 minutes
- Between 4 and 6 minutes
- Between 2 and 4 minutes
- Less than 2 minutes

Q16 I mainly use GPS tracking (select up to 3)

- Never or seldom
- To track and manage player load and performance during the WHOLE TRAINING SESSION
- To track and manage player load and performance during SSGs SPECIFICALLY
- As a sporadic or regular form of player evaluation
- For selection purposes
- Other; please specify ____

Q17 Is there ANY ADDITIONAL INFORMATION you would like to add to complement your answers to the questions above?

____

INFORMED CONSENT By submitting this survey, I agree to participate in the study under the conditions outlined in the informational statement. I understand I cannot withdraw the information provided.

○ Yes, I agree to participate.

Appendix 10: Youth SSG general performance measures (imputed values - R)

Table I: 15 main performance variables

Youth		Small	Medium	Large
TD (m)	3v3	1488.1 ± 205.9 ^{AB}	1517.8 ± 298.5 ^{AB}	1644.1 ± 297.8 ^{B}
16 / 305 SSGs had missing measurements		(366.7 ± 55.8) ^{a}	(399.6 ± 60.8) ^{cd}	(442.5 ± 158.7) ^{e}
(48 / 1004 Bouts had missing measurements)	5v5	1275.4 ± 185.5 ^{C}	1497.5 ± 220.8 ^{ABC}	1617.6 ± 237.6 ^{B}
		(324.1 ± 56.3) ^{b}	(379.8 ± 48.8) ^{acd}	(419.1 ± 72.0) ^{de}
	7v7	1294.1 ± 125.3 ^{C}	1442.8 ± 172.7 ^{AC}	1646.0 ± 186.2 ^{B}
		(316.9 ± 37.3) ^{b}	(375.3 ± 65.5) ^{ac}	(390.6 ± 56.9) ^{acd}
Shapiro-Wilk Test: W = 0.92; p = <0.001. Levene's Test: F = 1.50; p = 0.157				
(Shapiro-Wilk Test: W = 0.71; p = <0.001. Levene's Test: F = 2.35; p = <0.001)				
RD (m·min^{-1})	3v3	82.1 ± 11.6 ^{A}	83.8 ± 15.8 ^{AC}	93.4 ± 15.2 ^{D}
16 / 305 SSGs had missing measurements		(91.7 ± 13.3) ^{a}	(99.1 ± 15.7) ^{cd}	(106.9 ± 19.7) ^{e}
(47 / 1004 Bouts had missing measurements)	5v5	70.8 ± 10.2 ^{B}	77.5 ± 11.3 ^{AB}	85.7 ± 12.4 ^{ACD}
		(80.1 ± 13.7) ^{b}	(91.8 ± 13.1) ^{ac}	(101.9 ± 17.1) ^{de}
	7v7	70.6 ± 7.0 ^{B}	77.2 ± 8.9 ^{AB}	90.9 ± 10.6 ^{CD}
		(79.0 ± 9.2) ^{b}	(92.1 ± 15.3) ^{a}	(97.2 ± 14.4) ^{acd}
Shapiro-Wilk Test: W = 0.95; p = <0.001. Levene's Test: F = 1.66; p = 0.107				
(Shapiro-Wilk Test: W = 0.99; p = <0.001. Levene's Test: F = 2.41; p = <0.001)				
V_{AVG} (km·h^{-1})	3v3	4.9 ± 0.7 ^{A}	5.0 ± 1.0 ^{AC}	5.6 ± 0.9 ^{D}
16 / 305 SSGs had missing measurements		(5.5 ± 0.8) ^{a}	(6.0 ± 0.9) ^{cd}	(6.4 ± 1.2) ^{e}
(47 / 1004 Bouts had missing measurements)	5v5	4.2 ± 0.6 ^{B}	4.7 ± 0.7 ^{AB}	5.1 ± 0.7 ^{ACD}
		(4.8 ± 0.8) ^{b}	(5.5 ± 0.8) ^{ac}	(6.1 ± 1.0) ^{de}
	7v7	4.2 ± 0.4 ^{B}	4.6 ± 0.5 ^{AB}	5.5 ± 0.6 ^{CD}
		(4.7 ± 0.6) ^{b}	(5.5 ± 0.9) ^{a}	(5.8 ± 0.9) ^{acd}
Shapiro-Wilk Test: W = 0.95; p = <0.001. Levene's Test: F = 1.69; p = 0.101				
(Shapiro-Wilk Test: W = 0.99; p = <0.001. Levene's Test: F = 2.45; p = <0.001)				
V_{MAX} (km·h^{-1})	3v3	24.6 ± 3.0 ^{AB}	25.1 ± 4.5 ^{AB}	26.6 ± 3.4 ^{B}
16 / 305 SSGs had missing measurements		(21.8 ± 3.3) ^{ab}	(23.4 ± 3.3) ^{de}	(24.3 ± 3.7) ^{e}
(47 / 1004 Bouts had missing measurements)	5v5	22.7 ± 2.7 ^{AC}	25.7 ± 3.2 ^{AB}	25.9 ± 3.9 ^{AB}
		(20.4 ± 3.7) ^{ac}	(22.8 ± 3.5) ^{bde}	(23.3 ± 4.4) ^{bde}
	7v7	21.7 ± 2.6 ^{C}	24.8 ± 3.2 ^{AB}	25.4 ± 3.5 ^{AB}
		(19.5 ± 2.6) ^{c}	(22.3 ± 3.7) ^{bd}	(22.3 ± 3.6) ^{bd}
Shapiro-Wilk Test: W = 0.96; p = <0.001. Levene's Test: F = 0.93; p = 0.489				
(Shapiro-Wilk Test: W = 1.00; p = 0.015. Levene's Test: F = 1.76; p = 0.011)				
HR_{AVG} (% HR_{MAX})	3v3	81.5 ± 5.5 ^{ABC}	82.2 ± 3.7 ^{BC}	82.6 ± 4.9 ^{B}
48 / 305 SSGs had missing measurements		(83.2 ± 6.8) ^{ab}	(84.2 ± 5.4) ^{b}	(84.8 ± 5.7) ^{b}
(151 / 1004 Bouts had missing measurements)	5v5	77.2 ± 7.2 ^{ABCD}	78.6 ± 4.2 ^{ABCD}	77.4 ± 8.2 ^{ACD}
		(79.9 ± 7.9) ^{ac}	(81.9 ± 4.8) ^{abc}	(80.5 ± 8.9) ^{ac}
	7v7	76.8 ± 6.3 ^{AD}	76.2 ± 6.7 ^{D}	79.4 ± 7.1 ^{ABCD}
		(79.0 ± 8.0) ^{c}	(79.0 ± 8.3) ^{c}	(81.2 ± 8.0) ^{ac}
Shapiro-Wilk Test: W = 0.96; p = <0.001. Levene's Test: F = 2.17; p = 0.030				

Youth		Small	Medium	Large
(Shapiro-Wilk Test: W = 0.95; *p* = <0.001. Levene’s Test: F = 1.90; *p* = 0.004)				
HR$_{MAX}$ (%HR$_{MAX}$)	3v3	94.6 ± 4.9 ^{A}	95.4 ± 3.8 ^{A}	95.5 ± 4.1 ^{A}
48 / 305 SSGs had missing measurements		(91.5 ± 6.4) ^{abc}	(93.0 ± 5.3) ^{bc}	(93.3 ± 4.7) ^{b}
(151 / 1004 Bouts had missing	5v5	92.0 ± 5.4 ^{A}	92.9 ± 4.8 ^{A}	92.4 ± 7.4 ^{A}
measurements)		(88.8 ± 7.4) ^{ad}	(91.6 ± 4.6) ^{abcd}	(89.6 ± 8.8) ^{ad}
	7v7	91.5 ± 4.9 ^{A}	91.8 ± 5.5 ^{A}	93.8 ± 5.7 ^{A}
		(88.1 ± 6.6) ^{d}	(88.3 ± 7.2) ^{d}	(90.3 ± 7.4) ^{acd}
Shapiro-Wilk Test: W = 0.93; *p* = <0.001. Levene’s Test: F = 0.89; *p* = 0.522				
(Shapiro-Wilk Test: W = 0.92; *p* = <0.001. Levene’s Test: F = 1.39; *p* = 0.095)				
RPE (6-20)	3v3	13.1 ± 2.8 ^{AB}	13.7 ± 2.3 ^{AD}	14.9 ± 2.4 ^{D}
3 / 305 SSGs had missing measurements		(12.5 ± 2.6) ^{a}	(12.6 ± 2.5) ^{a}	(13.6 ± 2.4) ^{e}
(2 / 1004 Bouts had missing	5v5	12.4 ± 1.8 ^{ABC}	14.3 ± 1.4 ^{AD}	13.3 ± 2.5 ^{ABD}
measurements)		(11.3 ± 1.7) ^{bc}	(12.2 ± 2.2) ^{ab}	(12.2 ± 2.8) ^{ab}
	7v7	10.4 ± 1.6 ^{C}	12.1 ± 2.8 ^{B}	12.4 ± 1.3 ^{AB}
		(9.4 ± 1.8) ^{d}	(11.0 ± 2.5) ^{c}	(12.0 ± 1.6) ^{ab}
Shapiro-Wilk Test: W = 0.99; *p* = 0.040. Levene’s Test: F = 3.47; *p* = <0.001				
(Shapiro-Wilk Test: W = 0.99; *p* = <0.001. Levene’s Test: F = 3.26; *p* = <0.001)				
Sprint·min^{-1}	3v3	2.0 ± 0.9 ^{A}	2.2 ± 0.6 ^{A}	2.0 ± 0.8 ^{A}
16 / 305 SSGs had missing measurements		(2.7 ± 1.3) ^{ab}	(2.9 ± 1.1) ^{b}	(2.7 ± 1.3) ^{ab}
(47 / 1004 Bouts had missing	5v5	1.9 ± 0.6 ^{A}	2.0 ± 0.5 ^{A}	2.0 ± 0.8 ^{A}
measurements)		(2.5 ± 1.1) ^{ab}	(2.7 ± 1.0) ^{ab}	(2.8 ± 1.3) ^{ab}
	7v7	1.7 ± 0.7 ^{A}	2.0 ± 0.7 ^{A}	2.1 ± 0.8 ^{A}
		(2.3 ± 1.0) ^{a}	(2.7 ± 1.2) ^{ab}	(2.6 ± 1.2) ^{ab}
Shapiro-Wilk Test: W = 0.95; *p* = <0.001. Levene’s Test: F = 1.16; *p* = 0.322				
(Shapiro-Wilk Test: W = 0.98; *p* = <0.001. Levene’s Test: F = 1.04; *p* = 0.408)				
HIacc	3v3	39.3 ± 11.9 ^{A}	33.6 ± 10.8 ^{AB}	29.2 ± 8.7 ^{B}
16 / 305 SSGs had missing measurements		(12.2 ± 4.4) ^{a}	(10.5 ± 3.8) ^{ab}	(9.6 ± 5.2) ^{b}
(47 / 1004 Bouts had missing	5v5	37.3 ± 11.8 ^{AB}	33.4 ± 7.2 ^{AB}	33.7 ± 14.5 ^{AB}
measurements)		(10.7 ± 5.3) ^{ab}	(10.6 ± 3.3) ^{ab}	(10.5 ± 5.1) ^{ab}
	7v7	31.3 ± 8.5 ^{AB}	34.3 ± 11.6 ^{AB}	33.2 ± 9.6 ^{AB}
		(9.4 ± 3.4) ^{b}	(10.6 ± 4.6) ^{ab}	(9.5 ± 4.2) ^{b}
Shapiro-Wilk Test: W = 1.00; *p* = 0.937. Levene’s Test: F = 1.82; *p* = 0.073				
(Shapiro-Wilk Test: W = 0.96; *p* = <0.001. Levene’s Test: F = 1.75; *p* = 0.012)				
HIdec	3v3	12.4 ± 5.3 ^{A}	12.3 ± 4.7 ^{A}	11.1 ± 5.5 ^{A}
16 / 305 SSGs had missing measurements		(3.8 ± 2.1) ^{ab}	(3.9 ± 1.9) ^{b}	(3.6 ± 2.4) ^{ab}
(47 / 1004 Bouts had missing	5v5	11.8 ± 5.3 ^{A}	11.0 ± 4.4 ^{A}	12.2 ± 5.3 ^{A}
measurements)		(3.3 ± 2.3) ^{ab}	(3.5 ± 2.0) ^{ab}	(3.9 ± 2.0) ^{ab}
	7v7	9.8 ± 5.1 ^{A}	11.4 ± 4.7 ^{A}	10.8 ± 5.5 ^{A}
		(3.0 ± 2.0) ^{a}	(3.5 ± 1.9) ^{ab}	(3.2 ± 2.1) ^{ab}
Shapiro-Wilk Test: W = 0.99; *p* = 0.004. Levene’s Test: F = 0.27; *p* = 0.974				
(Shapiro-Wilk Test: W = 0.98; *p* = <0.001. Levene’s Test: F = 1.05; *p* = 0.397)				

Youth		Small	Medium	Large
AL$_{3D}$ (AU)	3v3	3.7 ± 0.8 ^{AB}	3.6 ± 0.7 ^{AB}	4.1 ± 0.9 ^{B}
13 / 305 SSGs had missing measurements		(4.2 ± 0.9) ^{ab}	(4.5 ± 1.0) ^{ae}	(4.8 ± 1.3) ^{e}
	5v5	2.9 ± 0.6 ^{C}	3.4 ± 0.8 ^{ABC}	3.6 ± 0.8 ^{ABC}
(44 / 1004 Bouts had missing		(3.6 ± 0.9) ^{cd}	(4.2 ± 1.0) ^{abd}	(4.4 ± 1.2) ^{abe}
measurements)	7v7	3.0 ± 0.6 ^{C}	3.3 ± 0.7 ^{AC}	3.8 ± 0.6 ^{AB}
		(3.4 ± 0.8) ^{c}	(4.0 ± 1.0) ^{b}	(4.1 ± 0.9) ^{b}

Shapiro-Wilk Test: W = 0.99; *p* = 0.018. Levene’s Test: F = 1.58; *p* = 0.131

(Shapiro-Wilk Test: W = 1.00; *p* = 0.347. Levene’s Test: F = 1.87; *p* = 0.005)

Impact (min^{-1})	3v3	0.0 ± 0.0 ^{A}	0.0 ± 0.0 ^{A}	0.0 ± 0.0 ^{A}
16 / 305 SSGs had missing measurements		(0.0 ± 0.1) ^{a}	(0.0 ± 0.1) ^{a}	(0.0 ± 0.1) ^{a}
	5v5	0.0 ± 0.0 ^{A}	0.0 ± 0.0 ^{A}	0.0 ± 0.0 ^{A}
(47 / 1004 Bouts had missing		(0.0 ± 0.0) ^{a}	(0.0 ± 0.1) ^{a}	(0.0 ± 0.0) ^{a}
measurements)	7v7	0.0 ± 0.0 ^{A}	0.0 ± 0.0 ^{A}	0.0 ± 0.0 ^{A}
		(0.0 ± 0.1) ^{a}	(0.0 ± 0.1) ^{a}	(0.0 ± 0.1) ^{a}

Shapiro-Wilk Test: W = 0.70; *p* = <0.001. Levene’s Test: F = 1.59; *p* = 0.127

(Shapiro-Wilk Test: W = 0.47; *p* = <0.001. Levene’s Test: F = 1.34; *p* = 0.122)

HIRD (m)	3v3	53.5 ± 36.6 ^{AB}	104.7 ± 60.5 ^{C}	144.2 ± 74.7 ^{E}
30 / 305 SSGs had missing measurements		(16.4 ± 15.3) ^{ab}	(32.0 ± 25.2) ^{d}	(45.1 ± 33.4) ^{e}
	5v5	28.7 ± 20.7 ^{AB}	61.8 ± 43.8 ^{ABCD}	104.2 ± 63.6 ^{CDE}
(101 / 1004 Bouts had missing		(10.3 ± 11.3) ^{ac}	(20.2 ± 18.9) ^{ab}	(34.2 ± 27.0) ^{d}
measurements)	7v7	20.0 ± 20.4 ^{A}	69.2 ± 55.1 ^{BD}	58.1 ± 41.0 ^{AB}
		(5.5 ± 8.4) ^{c}	(20.9 ± 20.1) ^{b}	(17.4 ± 18.2) ^{ab}

Shapiro-Wilk Test: W = 0.98; *p* = <0.001. Levene’s Test: F = 6.80; *p* = <0.001

(Shapiro-Wilk Test: W = 0.94; *p* = <0.001. Levene’s Test: F = 7.30; *p* = <0.001)

HSRD (m)	3v3	26.6 ± 20.0 ^{A}	59.7 ± 45.9 ^{B}	98.6 ± 70.8 ^{C}
30 / 305 SSGs had missing measurements		(8.2 ± 9.8) ^{ab}	(18.3 ± 19.6) ^{cd}	(30.6 ± 30.7) ^{e}
	5v5	13.9 ± 12.9 ^{A}	36.2 ± 35.0 ^{AB}	63.9 ± 47.8 ^{B}
(101 / 1004 Bouts had missing		(5.6 ± 8.2) ^{ab}	(11.8 ± 14.8) ^{abcd}	(21.2 ± 20.5) ^{d}
measurements)	7v7	8.5 ± 12.6 ^{A}	39.6 ± 40.6 ^{AB}	31.9 ± 31.3 ^{AB}
		(2.2 ± 5.8) ^{a}	(12.0 ± 15.4) ^{bc}	(10.0 ± 14.2) ^{ab}

Shapiro-Wilk Test: W = 0.92; *p* = <0.001. Levene’s Test: F = 7.51; *p* = <0.001

(Shapiro-Wilk Test: W = 0.86; *p* = <0.001. Levene’s Test: F = 6.26; *p* = <0.001)

VHSRD (m)	3v3	2.8 ± 6.8 ^{A}	10.1 ± 14.4 ^{AB}	23.8 ± 45.2 ^{B}
32 / 305 SSGs had missing measurements		(0.8 ± 3.6) ^{a}	(3.1 ± 7.4) ^{a}	(7.4 ± 18.9) ^{b}
	5v5	0.3 ± 0.5 ^{A}	9.4 ± 17.9 ^{AB}	12.6 ± 19.3 ^{AB}
(103 / 1004 Bouts had missing		(0.4 ± 1.9) ^{a}	(3.0 ± 7.2) ^{ab}	(4.3 ± 8.9) ^{ab}
measurements)	7v7	0.7 ± 2.6 ^{A}	7.4 ± 13.9 ^{A}	6.6 ± 10.3 ^{A}
		(0.2 ± 1.5) ^{a}	(2.4 ± 6.6) ^{a}	(2.0 ± 5.6) ^{a}

Shapiro-Wilk Test: W = 0.60; *p* = <0.001. Levene’s Test: F = 3.93; *p* = <0.001

(Shapiro-Wilk Test: W = 0.51; *p* = <0.001. Levene’s Test: F = 3.00; *p* = <0.001)

Same grouping letter = not significantly different (H_0 not rejected at $p \leq 0.05$)

U14		Small	Medium	Large
TD (m)	3v3	1441.0 ± 111.8 ^{A}	1355.0 ± 500.1 ^{A}	1388.9 ± 378.4 ^{A}
16 / 305 SSGs had missing measurements		(354.8 ± 69.2) ^{abc}	(376.0 ± 67.7) ^{b}	(444.6 ± 302.7) ^{d}
(48 / 1004 Bouts had missing	5v5	—	1344.7 ± 126.2 ^{A}	—
measurements)		(291.1 ± 45.0) ^{a}	(359.2 ± 46.1) ^{bc}	(—)
	7v7	—	1251.6 ± 171.6 ^{A}	—
		(—)	(303.6 ± 59.4) ^{ac}	(326.6 ± 44.0) ^{abc}

Shapiro-Wilk Test: W = 0.91; *p* = <0.001. Levene's Test: F = 1.42; *p* = 0.082
(Shapiro-Wilk Test: W = 0.67; *p* = <0.001. Levene's Test: F = 1.25; *p* = 0.065)

		Small	Medium	Large
RD ($m \cdot min^{-1}$)	3v3	80.2 ± 5.7 ^{AB}	73.7 ± 25.6 ^{AB}	87.8 ± 22.1 ^{B}
16 / 305 SSGs had missing measurements		(88.0 ± 15.1) ^{abc}	(92.0 ± 17.2) ^{ab}	(97.7 ± 26.3) ^{b}
(47 / 1004 Bouts had missing	5v5	—	70.0 ± 6.6 ^{A}	—
measurements)		(71.2 ± 10.5) ^{d}	(85.0 ± 11.1) ^{ace}	(—)
	7v7	—	68.0 ± 9.7 ^{A}	—
		(—)	(74.8 ± 14.3) ^{de}	(80.2 ± 10.7) ^{cde}

Shapiro-Wilk Test: W = 0.93; *p* = <0.001. Levene's Test: F = 1.49; *p* = 0.057
(Shapiro-Wilk Test: W = 0.99; *p* = <0.001. Levene's Test: F = 1.49; *p* = 0.003)

		Small	Medium	Large
V_{AVG} ($km \cdot h^{-1}$)	3v3	4.8 ± 0.4 ^{AB}	4.4 ± 1.5 ^{AB}	5.3 ± 1.3 ^{B}
16 / 305 SSGs had missing measurements		(5.3 ± 0.9) ^{abc}	(5.5 ± 1.0) ^{ab}	(5.9 ± 1.6) ^{b}
(47 / 1004 Bouts had missing	5v5	—	4.2 ± 0.4 ^{A}	—
measurements)		(4.3 ± 0.6) ^{d}	(5.1 ± 0.7) ^{ace}	(—)
	7v7	—	4.1 ± 0.6 ^{A}	—
		(—)	(4.5 ± 0.9) ^{de}	(4.8 ± 0.7) ^{cde}

Shapiro-Wilk Test: W = 0.93; *p* = <0.001. Levene's Test: F = 1.46; *p* = 0.065
(Shapiro-Wilk Test: W = 0.99; *p* = <0.001. Levene's Test: F = 1.48; *p* = 0.003)

		Small	Medium	Large
V_{MAX} ($km \cdot h^{-1}$)	3v3	22.9 ± 2.9 ^{AB}	23.6 ± 7.4 ^{AB}	26.5 ± 5.4 ^{B}
16 / 305 SSGs had missing measurements		(20.3 ± 2.6) ^{ab}	(23.4 ± 3.4) ^{c}	(23.2 ± 4.7) ^{ac}
(47 / 1004 Bouts had missing	5v5	—	25.5 ± 3.2 ^{AB}	—
measurements)		(20.4 ± 5.3) ^{abc}	(22.2 ± 3.5) ^{ac}	(—)
	7v7	—	21.2 ± 1.8 ^{A}	—
		(—)	(18.6 ± 2.6) ^{b}	(21.3 ± 3.9) ^{abc}

Shapiro-Wilk Test: W = 0.95; *p* = <0.001. Levene's Test: F = 1.01; *p* = 0.454
(Shapiro-Wilk Test: W = 1.00; *p* = 0.011. Levene's Test: F = 1.23; *p* = 0.082)

		Small	Medium	Large
HR_{AVG} (% HR_{MAX})	3v3	81.5 ± 2.5 ^{A}	82.9 ± 6.2 ^{A}	82.2 ± 6.7 ^{A}
48 / 305 SSGs had missing measurements		(82.2 ± 8.2) ^{ab}	(82.9 ± 8.3) ^{a}	(84.0 ± 6.7) ^{a}
(151 / 1004 Bouts had missing	5v5	—	77.8 ± 4.2 ^{A}	—
measurements)		(79.7 ± 5.8) ^{ab}	(81.3 ± 4.7) ^{ab}	(—)
	7v7	—	68.2 ± 6.2 ^{B}	—
		(—)	(70.1 ± 8.4) ^{c}	(77.0 ± 6.3) ^{b}

Shapiro-Wilk Test: W = 0.96; *p* = <0.001. Levene's Test: F = 1.33; *p* = 0.129
(Shapiro-Wilk Test: W = 0.96; *p* = <0.001. Levene's Test: F = 1.24; *p* = 0.070)

		Small	Medium	Large
HR_{MAX} (%HR_{MAX})	3v3	95.2 ± 2.8 ^{A}	97.4 ± 6.2 ^{A}	95.4 ± 5.6 ^{A}
48 / 305 SSGs had missing measurements		(90.3 ± 9.6) ^{ab}	(92.8 ± 8.1) ^{a}	(93.2 ± 5.6) ^{a}

U14		Small	Medium	Large
(151 / 1004 Bouts had missing measurements)	5v5	—	93.7 ± 4.7 ^{A}	—
		(89.3 ± 6.9) ^{ab}	(92.1 ± 4.5) ^{ab}	(—)
	7v7	—	84.2 ± 5.6 ^{B}	—
		(—)	(80.3 ± 7.2) ^{c}	(87.0 ± 6.1) ^{b}
Shapiro-Wilk Test: W = 0.93; *p* = <0.001. Levene's Test: F = 0.86; *p* = 0.682				
(Shapiro-Wilk Test: W = 0.92; *p* = <0.001. Levene's Test: F = 0.98; *p* = 0.530)				
RPE (6-20)	3v3	9.6 ± 0.9 ^{AB}	12.5 ± 2.8 ^{AC}	13.2 ± 2.3 ^{C}
3 / 305 SSGs had missing measurements		(9.8 ± 2.4) ^{ab}	(11.0 ± 2.6) ^{ac}	(11.6 ± 1.9) ^{cd}
(2 / 1004 Bouts had missing measurements)	5v5	—	14.7 ± 1.6 ^{C}	—
		(11.3 ± 1.6) ^{acd}	(12.6 ± 2.2) ^{d}	(—)
	7v7	—	9.3 ± 1.7 ^{B}	—
		(—)	(8.8 ± 1.9) ^{b}	(11.3 ± 2.0) ^{acd}
Shapiro-Wilk Test: W = 0.98; *p* = 0.001. Levene's Test: F = 2.35; *p* = <0.001				
(Shapiro-Wilk Test: W = 0.99; *p* = <0.001. Levene's Test: F = 1.95; *p* = <0.001)				
Sprint·min^{-1}	3v3	2.1 ± 0.3 ^{A}	1.9 ± 0.7 ^{A}	1.4 ± 1.1 ^{A}
16 / 305 SSGs had missing measurements		(2.5 ± 1.0) ^{a}	(2.3 ± 1.1) ^{ab}	(1.9 ± 1.4) ^{ab}
(47 / 1004 Bouts had missing measurements)	5v5	—	1.7 ± 0.4 ^{A}	—
		(1.7 ± 0.9) ^{ab}	(2.5 ± 0.8) ^{a}	(—)
	7v7	—	1.2 ± 0.7 ^{A}	—
		(—)	(1.6 ± 0.9) ^{b}	(1.8 ± 0.8) ^{ab}
Shapiro-Wilk Test: W = 0.97; *p* = <0.001. Levene's Test: F = 2.55; *p* = <0.001				
(Shapiro-Wilk Test: W = 0.99; *p* = <0.001. Levene's Test: F = 1.73; *p* = <0.001)				
HIacc	3v3	39.2 ± 7.8 ^{A}	35.3 ± 13.2 ^{A}	28.0 ± 10.4 ^{A}
16 / 305 SSGs had missing measurements		(11.0 ± 3.7) ^{a}	(10.7 ± 3.7) ^{a}	(10.0 ± 8.6) ^{ab}
(47 / 1004 Bouts had missing measurements)	5v5	—	31.7 ± 7.9 ^{A}	—
		(6.5 ± 3.6) ^{b}	(10.0 ± 3.2) ^{ab}	(—)
	7v7	—	23.7 ± 8.2 ^{A}	—
		(—)	(6.9 ± 3.3) ^{b}	(6.8 ± 3.1) ^{b}
Shapiro-Wilk Test: W = 1.00; *p* = 0.659. Levene's Test: F = 1.22; *p* = 0.208				
(Shapiro-Wilk Test: W = 0.96; *p* = <0.001. Levene's Test: F = 1.34; *p* = 0.022)				
HIdec	3v3	9.0 ± 2.3 ^{A}	11.3 ± 4.8 ^{A}	9.0 ± 3.5 ^{A}
16 / 305 SSGs had missing measurements		(2.8 ± 1.5) ^{ab}	(3.6 ± 1.7) ^{b}	(3.3 ± 2.7) ^{ab}
(47 / 1004 Bouts had missing measurements)	5v5	—	10.3 ± 4.6 ^{A}	—
		(1.8 ± 1.7) ^{a}	(3.3 ± 2.0) ^{ab}	(—)
	7v7	—	6.6 ± 1.6 ^{A}	—
		(—)	(2.0 ± 1.1) ^{ab}	(2.3 ± 1.4) ^{ab}
Shapiro-Wilk Test: W = 0.99; *p* = 0.258. Levene's Test: F = 0.98; *p* = 0.493				
(Shapiro-Wilk Test: W = 0.98; *p* = <0.001. Levene's Test: F = 0.93; *p* = 0.663)				
AL_{3D} (AU)	3v3	3.6 ± 0.5 ^{A}	3.2 ± 1.1 ^{A}	3.7 ± 1.3 ^{A}
13 / 305 SSGs had missing measurements		(4.0 ± 1.0) ^{a}	(4.2 ± 0.9) ^{a}	(4.2 ± 1.3) ^{a}
(44 / 1004 Bouts had missing measurements)	5v5	—	3.0 ± 0.7 ^{A}	—
		(3.0 ± 0.7) ^{b}	(3.8 ± 0.9) ^{ab}	(—)

U14		Small	Medium	Large
	7v7	—	2.8 ± 0.5 [A]	—
		(—)	(3.1 ± 0.7) [b]	(3.1 ± 0.7) [b]
Shapiro-Wilk Test: W = 0.99; *p* = 0.007. Levene's Test: F = 0.71; *p* = 0.870				
(Shapiro-Wilk Test: W = 1.00; *p* = 0.004. Levene's Test: F = 1.08; *p* = 0.288)				
Impact (min^{-1})	3v3	0.0 ± 0.0 [A]	0.0 ± 0.0 [A]	0.0 ± 0.0 [A]
16 / 305 SSGs had missing measurements		(0.0 ± 0.1) [a]	(0.0 ± 0.1) [a]	(0.0 ± 0.1) [a]
(47 / 1004 Bouts had missing measurements)	5v5	—	0.0 ± 0.0 [A]	—
		(0.0 ± 0.1) [a]	(0.0 ± 0.1) [a]	(—)
	7v7	—	0.0 ± 0.0 [A]	—
		(—)	(0.0 ± 0.1) [a]	(0.0 ± 0.1) [a]
Shapiro-Wilk Test: W = 0.78; *p* = <0.001. Levene's Test: F = 0.76; *p* = 0.806				
(Shapiro-Wilk Test: W = 0.58; *p* = <0.001. Levene's Test: F = 1.06; *p* = 0.342)				
HIRD (m)	3v3	26.2 ± 22.2 [A]	85.1 ± 44.6 [AB]	136.5 ± 117.2 [B]
30 / 305 SSGs had missing measurements		(8.1 ± 10.0) [a]	(24.7 ± 18.0) [bc]	(39.8 ± 46.0) [c]
(101 / 1004 Bouts had missing measurements)	5v5	—	55.5 ± 35.2 [AB]	—
		(12.6 ± 13.6) [ab]	(16.5 ± 15.1) [ab]	(—)
	7v7	—	25.9 ± 34.6 [A]	—
		(—)	(6.3 ± 10.6) [a]	(12.3 ± 12.2) [ab]
Shapiro-Wilk Test: W = 0.98; *p* = <0.001. Levene's Test: F = 2.16; *p* = <0.001				
(Shapiro-Wilk Test: W = 0.95; *p* = <0.001. Levene's Test: F = 2.51; *p* = <0.001)				
HSRD (m)	3v3	15.8 ± 13.9 [A]	41.4 ± 28.8 [A]	137.8 ± 127.3 [B]
30 / 305 SSGs had missing measurements		(4.1 ± 7.1) [a]	(12.4 ± 11.6) [a]	(37.7 ± 50.9) [b]
(101 / 1004 Bouts had missing measurements)	5v5	—	31.1 ± 25.7 [A]	—
		(8.3 ± 10.5) [a]	(9.1 ± 11.7) [a]	(—)
	7v7	—	9.8 ± 14.2 [A]	—
		(—)	(2.5 ± 5.3) [a]	(8.1 ± 10.1) [a]
Shapiro-Wilk Test: W = 0.95; *p* = <0.001. Levene's Test: F = 4.31; *p* = <0.001				
(Shapiro-Wilk Test: W = 0.89; *p* = <0.001. Levene's Test: F = 2.95; *p* = <0.001)				
VHSRD (m)	3v3	0.0 ± 0.0 [A]	5.3 ± 5.7 [A]	57.7 ± 94.0 [B]
32 / 305 SSGs had missing measurements		(0.0 ± 0.0) [a]	(1.4 ± 3.0) [a]	(15.7 ± 35.7) [b]
(103 / 1004 Bouts had missing measurements)	5v5	—	5.0 ± 6.1 [A]	—
		(1.0 ± 3.6) [a]	(1.3 ± 3.6) [a]	(—)
	7v7	—	0.0 ± 0.0 [A]	—
		(—)	(0.0 ± 0.0) [a]	(1.2 ± 4.0) [a]
Shapiro-Wilk Test: W = 0.66; *p* = <0.001. Levene's Test: F = 2.97; *p* = <0.001				
(Shapiro-Wilk Test: W = 0.58; *p* = <0.001. Levene's Test: F = 1.80; *p* = <0.001)				

Same grouping letter = not significantly different (H_0 not rejected at $p \leq 0.05$)

U15		Small	Medium	Large
TD (m)	3v3	1783.6 ± 202.3 ^{A}	1625.8 ± 175.4 ^{AC}	1785.6 ± 156.8 ^{A}
16 / 305 SSGs had missing measurements		(395.5 ± 57.3) ^{ab}	(372.7 ± 61.3) ^{ab}	(399.2 ± 67.4) ^{ab}
(48 / 1004 Bouts had missing measurements)	5v5	1214.6 ± 153.1 ^{B}	—	1517.4 ± 206.0 ^{AC}
		(335.2 ± 55.1) ^{ac}	(—)	(431.0 ± 68.9) ^{b}
	7v7	1213.2 ± 124.2 ^{B}	1459.4 ± 137.3 ^{C}	1510.4 ± 150.5 ^{AC}
		(298.6 ± 36.4) ^{c}	(400.7 ± 58.7) ^{b}	(392.5 ± 45.8) ^{b}

Shapiro-Wilk Test: W = 0.91; *p* = <0.001. Levene's Test: F = 1.42; *p* = 0.082
(Shapiro-Wilk Test: W = 0.67; *p* = <0.001. Levene's Test: F = 1.25; *p* = 0.065)

RD (m·min^{-1})	3v3	98.4 ± 11.3 ^{A}	89.8 ± 9.7 ^{AD}	97.4 ± 7.4 ^{A}
16 / 305 SSGs had missing measurements		(98.7 ± 14.2) ^{a}	(91.6 ± 14.7) ^{ac}	(97.9 ± 14.9) ^{a}
(47 / 1004 Bouts had missing measurements)	5v5	67.6 ± 8.4 ^{BC}	—	83.0 ± 11.3 ^{AD}
		(83.5 ± 13.6) ^{bc}	(—)	(102.5 ± 16.2) ^{a}
	7v7	65.9 ± 6.6 ^{B}	77.8 ± 6.9 ^{CD}	83.1 ± 8.3 ^{AD}
		(74.1 ± 8.6) ^{b}	(97.5 ± 13.3) ^{a}	(97.4 ± 11.0) ^{a}

Shapiro-Wilk Test: W = 0.93; *p* = <0.001. Levene's Test: F = 1.49; *p* = 0.057
(Shapiro-Wilk Test: W = 0.99; *p* = <0.001. Levene's Test: F = 1.49; *p* = 0.003)

V_{AVG} (km·h^{-1})	3v3	5.9 ± 0.7 ^{A}	5.4 ± 0.6 ^{AC}	5.8 ± 0.4 ^{A}
16 / 305 SSGs had missing measurements		(5.9 ± 0.8) ^{a}	(5.5 ± 0.9) ^{ac}	(5.9 ± 0.9) ^{a}
(47 / 1004 Bouts had missing measurements)	5v5	4.1 ± 0.5 ^{B}	—	5.0 ± 0.7 ^{AC}
		(5.0 ± 0.8) ^{bc}	(—)	(6.2 ± 1.0) ^{a}
	7v7	4.0 ± 0.4 ^{B}	4.6 ± 0.4 ^{BC}	5.0 ± 0.5 ^{AC}
		(4.4 ± 0.5) ^{b}	(5.8 ± 0.8) ^{a}	(5.8 ± 0.7) ^{a}

Shapiro-Wilk Test: W = 0.93; *p* = <0.001. Levene's Test: F = 1.46; *p* = 0.065
(Shapiro-Wilk Test: W = 0.99; *p* = <0.001. Levene's Test: F = 1.48; *p* = 0.003)

V_{MAX} (km·h^{-1})	3v3	24.1 ± 2.6 ^{A}	25.0 ± 3.2 ^{A}	26.9 ± 3.2 ^{A}
16 / 305 SSGs had missing measurements		(21.6 ± 2.9) ^{ab}	(22.6 ± 3.7) ^{ab}	(23.7 ± 4.0) ^{b}
(47 / 1004 Bouts had missing measurements)	5v5	22.5 ± 2.1 ^{A}	—	25.6 ± 3.4 ^{A}
		(20.1 ± 2.7) ^{a}	(—)	(23.8 ± 3.6) ^{b}
	7v7	23.2 ± 2.9 ^{A}	25.2 ± 2.8 ^{A}	24.9 ± 2.8 ^{A}
		(20.3 ± 3.2) ^{a}	(23.0 ± 3.0) ^{b}	(22.4 ± 3.1) ^{ab}

Shapiro-Wilk Test: W = 0.95; *p* = <0.001. Levene's Test: F = 1.01; *p* = 0.454
(Shapiro-Wilk Test: W = 1.00; *p* = 0.011. Levene's Test: F = 1.23; *p* = 0.082)

HR_{AVG} (% HR_{MAX})	3v3	87.1 ± 4.0 ^{A}	81.9 ± 4.0 ^{AB}	85.3 ± 6.5 ^{A}
48 / 305 SSGs had missing measurements		(88.0 ± 5.4) ^{a}	(83.7 ± 5.3) ^{ab}	(85.3 ± 8.6) ^{ab}
(151 / 1004 Bouts had missing measurements)	5v5	79.0 ± 5.3 ^{AB}	—	78.7 ± 5.6 ^{AB}
		(82.1 ± 6.9) ^{ab}	(—)	(82.2 ± 5.6) ^{ab}
	7v7	71.4 ± 5.0 ^{B}	76.3 ± 6.1 ^{B}	78.7 ± 7.8 ^{AB}
		(72.2 ± 6.3) ^{c}	(79.6 ± 7.3) ^{b}	(83.0 ± 6.7) ^{ab}

Shapiro-Wilk Test: W = 0.96; *p* = <0.001. Levene's Test: F = 1.33; *p* = 0.129
(Shapiro-Wilk Test: W = 0.96; *p* = <0.001. Levene's Test: F = 1.24; *p* = 0.070)

HR_{MAX} (%HR_{MAX})	3v3	98.7 ± 5.2 ^{A}	95.1 ± 3.8 ^{AB}	96.4 ± 5.0 ^{A}
48 / 305 SSGs had missing measurements		(96.0 ± 4.9) ^{a}	(92.7 ± 4.4) ^{ab}	(94.1 ± 5.8) ^{ab}

U15		Small	Medium	Large
(151 / 1004 Bouts had missing measurements)	5v5	94.9 ± 4.3 ^{AB}	—	94.5 ± 3.5 ^{AB}
		(90.9 ± 6.8) ^{ab}	(—)	(92.2 ± 4.0) ^{ab}
	7v7	87.9 ± 4.9 ^{B}	93.0 ± 4.5 ^{AB}	94.8 ± 4.9 ^{A}
		(83.3 ± 6.5) ^{c}	(89.6 ± 6.5) ^{b}	(93.1 ± 5.3) ^{ab}

Shapiro-Wilk Test: W = 0.93; *p* = <0.001. Levene's Test: F = 0.86; *p* = 0.682

(Shapiro-Wilk Test: W = 0.92; *p* = <0.001. Levene's Test: F = 0.98; *p* = 0.530)

RPE (6-20)	3v3	12.7 ± 0.8 ^{A}	12.5 ± 1.2 ^{A}	12.5 ± 2.6 ^{A}
3 / 305 SSGs had missing measurements		(12.7 ± 0.9) ^{ab}	(12.1 ± 1.3) ^{ab}	(12.2 ± 1.8) ^{ab}
(2 / 1004 Bouts had missing measurements)	5v5	12.0 ± 2.3 ^{A}	—	13.9 ± 1.2 ^{A}
		(10.9 ± 1.9) ^{a}	(—)	(13.3 ± 1.2) ^{b}
	7v7	9.3 ± 1.4 ^{B}	12.3 ± 2.9 ^{A}	12.4 ± 0.9 ^{A}
		(8.7 ± 1.9) ^{c}	(11.4 ± 2.4) ^{a}	(12.0 ± 1.1) ^{ab}

Shapiro-Wilk Test: W = 0.98; *p* = 0.001. Levene's Test: F = 2.35; *p* = <0.001

(Shapiro-Wilk Test: W = 0.99; *p* = <0.001. Levene's Test: F = 1.95; *p* = <0.001)

Sprint·min^{-1}	3v3	2.1 ± 0.3 ^{A}	1.7 ± 0.3 ^{A}	2.0 ± 0.4 ^{A}
16 / 305 SSGs had missing measurements		(2.9 ± 0.8) ^{abc}	(2.2 ± 0.6) ^{ac}	(2.4 ± 0.8) ^{abc}
(47 / 1004 Bouts had missing measurements)	5v5	1.9 ± 0.6 ^{A}	—	2.2 ± 0.6 ^{A}
		(2.8 ± 1.2) ^{ab}	(—)	(3.3 ± 1.0) ^{b}
	7v7	1.5 ± 0.5 ^{A}	2.2 ± 0.5 ^{A}	1.8 ± 0.7 ^{A}
		(1.9 ± 0.7) ^{c}	(3.0 ± 1.1) ^{ab}	(2.6 ± 1.2) ^{abc}

Shapiro-Wilk Test: W = 0.97; *p* = <0.001. Levene's Test: F = 2.55; *p* = <0.001

(Shapiro-Wilk Test: W = 0.99; *p* = <0.001. Levene's Test: F = 1.73; *p* = <0.001)

HIacc	3v3	37.0 ± 6.7 ^{AB}	27.7 ± 10.0 ^{AB}	28.8 ± 6.8 ^{AB}
16 / 305 SSGs had missing measurements		(11.6 ± 3.3) ^{abc}	(8.0 ± 3.0) ^{b}	(8.4 ± 3.2) ^{bc}
(47 / 1004 Bouts had missing	5v5	39.1 ± 12.7 ^{AB}	—	38.3 ± 11.9 ^{AB}
measurements)		(12.7 ± 5.2) ^{a}	(—)	(12.4 ± 4.4) ^{ac}
	7v7	27.1 ± 7.9 ^{A}	39.5 ± 11.4 ^{B}	34.4 ± 9.4 ^{AB}
		(7.7 ± 2.7) ^{b}	(12.5 ± 4.5) ^{a}	(10.4 ± 3.7) ^{abc}

Shapiro-Wilk Test: W = 1.00; *p* = 0.659. Levene's Test: F = 1.22; *p* = 0.208

(Shapiro-Wilk Test: W = 0.96; *p* = <0.001. Levene's Test: F = 1.34; *p* = 0.022)

HIdec	3v3	10.6 ± 2.5 ^{AB}	11.0 ± 6.1 ^{AB}	9.0 ± 3.4 ^{AB}
16 / 305 SSGs had missing measurements		(3.5 ± 1.8) ^{abc}	(3.3 ± 2.4) ^{abc}	(2.6 ± 1.3) ^{ab}
(47 / 1004 Bouts had missing measurements)	5v5	10.9 ± 4.9 ^{AB}	—	15.0 ± 3.6 ^{B}
		(3.5 ± 2.1) ^{abc}	(—)	(4.9 ± 1.5) ^{c}
	7v7	7.8 ± 5.0 ^{A}	12.8 ± 4.7 ^{AB}	10.3 ± 5.0 ^{AB}
		(2.2 ± 1.8) ^{a}	(3.9 ± 1.9) ^{bc}	(3.2 ± 1.9) ^{ab}

Shapiro-Wilk Test: W = 0.99; *p* = 0.258. Levene's Test: F = 0.98; *p* = 0.493

(Shapiro-Wilk Test: W = 0.98; *p* = <0.001. Levene's Test: F = 0.93; *p* = 0.663)

AL_{3D} (AU)	3v3	4.4 ± 0.9 ^{A}	3.8 ± 0.5 ^{AC}	4.1 ± 0.6 ^{AC}
13 / 305 SSGs had missing measurements		(4.5 ± 0.9) ^{ab}	(3.9 ± 0.9) ^{ab}	(4.1 ± 1.0) ^{ab}
(44 / 1004 Bouts had missing measurements)	5v5	2.9 ± 0.7 ^{BC}	—	3.7 ± 0.9 ^{AC}
		(3.8 ± 1.0) ^{a}	(—)	(4.7 ± 1.2) ^{b}

U15		Small	Medium	Large
	7v7	2.6 ± 0.6 ^{B}	3.4 ± 0.6 ^{AC}	3.5 ± 0.5 ^{AC}
		(2.9 ± 0.7) ^{c}	(4.3 ± 1.0) ^{ab}	(4.2 ± 0.7) ^{ab}
Shapiro-Wilk Test: W = 0.99; *p* = 0.007. Levene's Test: F = 0.71; *p* = 0.870				
(Shapiro-Wilk Test: W = 1.00; *p* = 0.004. Levene's Test: F = 1.08; *p* = 0.288)				
Impact (min^{-1})	3v3	0.0 ± 0.0 ^{A}	0.0 ± 0.0 ^{A}	0.0 ± 0.0 ^{A}
16 / 305 SSGs had missing measurements		(0.0 ± 0.1) ^{a}	(0.0 ± 0.1) ^{a}	(0.0 ± 0.1) ^{a}
(47 / 1004 Bouts had missing measurements)	5v5	0.0 ± 0.0 ^{A}	—	0.0 ± 0.0 ^{A}
		(0.0 ± 0.0) ^{a}	(—)	(0.0 ± 0.0) ^{a}
	7v7	0.0 ± 0.0 ^{A}	0.0 ± 0.0 ^{A}	0.0 ± 0.0 ^{A}
		(0.0 ± 0.1) ^{a}	(0.0 ± 0.1) ^{a}	(0.0 ± 0.1) ^{a}
Shapiro-Wilk Test: W = 0.78; *p* = <0.001. Levene's Test: F = 0.76; *p* = 0.806				
(Shapiro-Wilk Test: W = 0.58; *p* = <0.001. Levene's Test: F = 1.06; *p* = 0.342)				
HIRD (m)	3v3	56.6 ± 40.4 ^{ABC}	85.3 ± 75.2 ^{ABC}	108.8 ± 39.9 ^{BC}
30 / 305 SSGs had missing measurements		(18.9 ± 17.8) ^{abc}	(28.2 ± 26.7) ^{bc}	(32.6 ± 26.8) ^{bc}
(101 / 1004 Bouts had missing measurements)	5v5	19.5 ± 12.4 ^{A}	—	115.2 ± 60.7 ^{C}
		(6.3 ± 8.3) ^{a}	(—)	(37.9 ± 25.6) ^{c}
	7v7	30.2 ± 23.8 ^{AB}	79.8 ± 58.5 ^{ABC}	46.8 ± 29.9 ^{AB}
		(8.0 ± 10.8) ^{a}	(23.4 ± 20.1) ^{b}	(14.9 ± 14.3) ^{ab}
Shapiro-Wilk Test: W = 0.98; *p* = <0.001. Levene's Test: F = 2.16; *p* = <0.001				
(Shapiro-Wilk Test: W = 0.95; *p* = <0.001. Levene's Test: F = 2.51; *p* = <0.001)				
HSRD (m)	3v3	27.6 ± 20.0 ^{A}	49.0 ± 50.1 ^{A}	74.8 ± 40.2 ^{A}
30 / 305 SSGs had missing measurements		(9.2 ± 11.1) ^{abc}	(16.2 ± 19.0) ^{abc}	(22.2 ± 23.8) ^{bc}
(101 / 1004 Bouts had missing measurements)	5v5	9.1 ± 8.8 ^{A}	—	64.7 ± 39.1 ^{A}
		(3.1 ± 5.6) ^{a}	(—)	(21.4 ± 16.3) ^{b}
	7v7	15.5 ± 14.9 ^{A}	44.2 ± 41.8 ^{A}	23.5 ± 21.9 ^{A}
		(4.1 ± 7.8) ^{a}	(12.8 ± 14.5) ^{abc}	(7.6 ± 10.5) ^{ac}
Shapiro-Wilk Test: W = 0.95; *p* = <0.001. Levene's Test: F = 4.31; *p* = <0.001				
(Shapiro-Wilk Test: W = 0.89; *p* = <0.001. Levene's Test: F = 2.95; *p* = <0.001)				
VHSRD (m)	3v3	1.0 ± 1.7 ^{A}	5.2 ± 7.0 ^{A}	17.8 ± 22.9 ^{A}
32 / 305 SSGs had missing measurements		(0.3 ± 1.0) ^{a}	(1.7 ± 3.8) ^{a}	(5.4 ± 13.3) ^{a}
(103 / 1004 Bouts had missing measurements)	5v5	0.1 ± 0.4 ^{A}	—	6.9 ± 12.2 ^{A}
		(0.0 ± 0.2) ^{a}	(—)	(2.4 ± 5.0) ^{a}
	7v7	1.4 ± 3.5 ^{A}	5.3 ± 7.6 ^{A}	3.3 ± 6.2 ^{A}
		(0.4 ± 2.1) ^{a}	(1.7 ± 4.1) ^{a}	(1.1 ± 3.6) ^{a}
Shapiro-Wilk Test: W = 0.66; *p* = <0.001. Levene's Test: F = 2.97; *p* = <0.001				
(Shapiro-Wilk Test: W = 0.58; *p* = <0.001. Levene's Test: F = 1.80; *p* = <0.001)				

Same grouping letter = not significantly different (H_0 not rejected at $p \leq 0.05$)

U16		Small	Medium	Large
TD (m)	3v3	1458.2 ± 53.6 ^{AB}	1644.2 ± 126.7 ^{AB}	1728.9 ± 197.4 ^{AB}
16 / 305 SSGs had missing measurements		(372.5 ± 31.4) ^{ab}	(439.3 ± 46.4) ^{bc}	(462.8 ± 53.7) ^{c}
(48 / 1004 Bouts had missing measurements)	5v5	1538.0 ± N/A ^{AB}	1852.0 ± N/A ^{AB}	—
		(391.3 ± 25.8) ^{abc}	(425.7 ± 13.3) ^{abc}	(—)
	7v7	1391.8 ± 76.3 ^{A}	1635.0 ± 105.4 ^{AB}	1818.4 ± 184.4 ^{B}
		(343.6 ± 29.0) ^{a}	(379.2 ± 54.2) ^{ab}	(437.8 ± 58.5) ^{bc}
Shapiro-Wilk Test: W = 0.91; *p* = <0.001. Levene's Test: F = 1.42; *p* = 0.082				
(Shapiro-Wilk Test: W = 0.67; *p* = <0.001. Levene's Test: F = 1.25; *p* = 0.065)				
RD ($m\cdot min^{-1}$)	3v3	80.8 ± 4.1 ^{AB}	91.2 ± 6.5 ^{AB}	96.0 ± 11.2 ^{AB}
16 / 305 SSGs had missing measurements		(93.0 ± 8.2) ^{a}	(110.2 ± 11.8) ^{b}	(115.7 ± 13.8) ^{b}
(47 / 1004 Bouts had missing measurements)	5v5	85.0 ± N/A ^{AB}	92.0 ± N/A ^{AB}	—
		(96.7 ± 3.8) ^{abc}	(105.3 ± 3.2) ^{abc}	(—)
	7v7	76.2 ± 4.2 ^{A}	87.2 ± 5.4 ^{AB}	101.0 ± 10.1 ^{B}
		(86.1 ± 7.1) ^{a}	(94.4 ± 13.3) ^{ac}	(109.3 ± 14.6) ^{bc}
Shapiro-Wilk Test: W = 0.93; *p* = <0.001. Levene's Test: F = 1.49; *p* = 0.057				
(Shapiro-Wilk Test: W = 0.99; *p* = <0.001. Levene's Test: F = 1.49; *p* = 0.003)				
V_{AVG} ($km\cdot h^{-1}$)	3v3	4.8 ± 0.3 ^{AB}	5.5 ± 0.4 ^{AB}	5.8 ± 0.7 ^{AB}
16 / 305 SSGs had missing measurements		(5.6 ± 0.5) ^{a}	(6.6 ± 0.7) ^{b}	(6.9 ± 0.8) ^{b}
(47 / 1004 Bouts had missing measurements)	5v5	5.1 ± N/A ^{AB}	5.5 ± N/A ^{AB}	—
		(5.8 ± 0.2) ^{abc}	(6.4 ± 0.2) ^{abc}	(—)
	7v7	4.6 ± 0.2 ^{A}	5.2 ± 0.3 ^{AB}	6.1 ± 0.6 ^{B}
		(5.2 ± 0.4) ^{a}	(5.7 ± 0.8) ^{ac}	(6.6 ± 0.9) ^{bc}
Shapiro-Wilk Test: W = 0.93; *p* = <0.001. Levene's Test: F = 1.46; *p* = 0.065				
(Shapiro-Wilk Test: W = 0.99; *p* = <0.001. Levene's Test: F = 1.48; *p* = 0.003)				
V_{MAX} ($km\cdot h^{-1}$)	3v3	23.2 ± 1.8 ^{A}	25.6 ± 3.1 ^{A}	26.5 ± 2.1 ^{A}
16 / 305 SSGs had missing measurements		(20.9 ± 2.6) ^{ab}	(23.3 ± 3.0) ^{b}	(24.6 ± 2.8) ^{b}
(47 / 1004 Bouts had missing measurements)	5v5	21.5 ± N/A ^{A}	20.3 ± N/A ^{A}	—
		(19.8 ± 1.9) ^{ab}	(20.0 ± 0.3) ^{ab}	(—)
	7v7	20.3 ± 0.7 ^{A}	24.7 ± 3.5 ^{A}	25.0 ± 3.7 ^{A}
		(19.1 ± 1.5) ^{a}	(22.3 ± 3.5) ^{ab}	(21.9 ± 3.8) ^{ab}
Shapiro-Wilk Test: W = 0.95; *p* = <0.001. Levene's Test: F = 1.01; *p* = 0.454				
(Shapiro-Wilk Test: W = 1.00; *p* = 0.011. Levene's Test: F = 1.23; *p* = 0.082)				
HR_{AVG} (% HR_{MAX})	3v3	77.7 ± 4.7 ^{A}	81.9 ± 2.1 ^{A}	83.1 ± 2.7 ^{A}
48 / 305 SSGs had missing measurements		(81.4 ± 4.7) ^{a}	(85.0 ± 2.9) ^{a}	(86.1 ± 3.5) ^{a}
(151 / 1004 Bouts had missing measurements)	5v5	82.8 ± N/A ^{A}	81.8 ± N/A ^{A}	—
		(85.2 ± 3.2) ^{a}	(85.9 ± 2.0) ^{a}	(—)
	7v7	77.6 ± 2.7 ^{A}	75.5 ± 2.5 ^{A}	81.5 ± 4.4 ^{A}
		(80.1 ± 3.6) ^{a}	(78.3 ± 5.4) ^{a}	(83.2 ± 5.3) ^{a}
Shapiro-Wilk Test: W = 0.96; *p* = <0.001. Levene's Test: F = 1.33; *p* = 0.129				
(Shapiro-Wilk Test: W = 0.96; *p* = <0.001. Levene's Test: F = 1.24; *p* = 0.070)				
HR_{MAX} (%HR_{MAX})	3v3	92.0 ± 4.3 ^{A}	95.5 ± 1.4 ^{A}	97.5 ± 2.5 ^{A}
48 / 305 SSGs had missing measurements		(90.6 ± 4.2) ^{ab}	(93.7 ± 2.8) ^{ab}	(95.0 ± 3.3) ^{b}

U16		Small	Medium	Large
(151 / 1004 Bouts had missing measurements)	5v5	95.6 ± N/A [A]	96.6 ± N/A [A]	—
		(93.3 ± 1.4) [ab]	(94.4 ± 2.0) [ab]	(—)
	7v7	93.2 ± 1.7 [A]	90.7 ± 1.4 [A]	95.5 ± 3.3 [A]
		(90.6 ± 2.7) [ab]	(86.4 ± 5.1) [a]	(91.7 ± 5.8) [ab]
Shapiro-Wilk Test: W = 0.93; *p* = <0.001. Levene's Test: F = 0.86; *p* = 0.682				
(Shapiro-Wilk Test: W = 0.92; *p* = <0.001. Levene's Test: F = 0.98; *p* = 0.530)				
RPE (6-20)	3v3	13.0 ± 2.2 [AB]	13.6 ± 2.2 [AB]	16.3 ± 1.1 [B]
3 / 305 SSGs had missing measurements		(12.4 ± 1.9) [ab]	(12.9 ± 2.2) [b]	(14.8 ± 2.1) [c]
(2 / 1004 Bouts had missing measurements)	5v5	12.0 ± N/A [AB]	14.0 ± 1.4 [AB]	—
		(11.0 ± 1.0) [ab]	(11.3 ± 2.6) [ab]	(—)
	7v7	11.0 ± 1.4 [A]	14.2 ± 2.1 [AB]	12.0 ± 1.2 [A]
		(10.0 ± 1.5) [a]	(11.7 ± 2.4) [ab]	(11.5 ± 1.6) [ab]
Shapiro-Wilk Test: W = 0.98; *p* = 0.001. Levene's Test: F = 2.35; *p* = <0.001				
(Shapiro-Wilk Test: W = 0.99; *p* = <0.001. Levene's Test: F = 1.95; *p* = <0.001)				
Sprint·min^{-1}	3v3	1.1 ± 1.3 [A]	2.6 ± 0.4 [B]	2.2 ± 1.2 [AB]
16 / 305 SSGs had missing measurements		(1.6 ± 1.7) [a]	(3.9 ± 0.8) [c]	(3.1 ± 1.6) [bc]
(47 / 1004 Bouts had missing measurements)	5v5	2.0 ± N/A [AB]	2.6 ± N/A [AB]	—
		(2.9 ± 0.5) [abc]	(3.8 ± 0.4) [abc]	(—)
	7v7	1.9 ± 1.4 [AB]	1.5 ± 1.1 [AB]	2.1 ± 1.4 [AB]
		(2.5 ± 1.7) [ab]	(2.0 ± 1.4) [ab]	(2.7 ± 1.8) [ab]
Shapiro-Wilk Test: W = 0.97; *p* = <0.001. Levene's Test: F = 2.55; *p* = <0.001				
(Shapiro-Wilk Test: W = 0.99; *p* = <0.001. Levene's Test: F = 1.73; *p* = <0.001)				
HIacc	3v3	36.2 ± 2.9 [A]	40.6 ± 5.2 [A]	32.9 ± 9.1 [A]
16 / 305 SSGs had missing measurements		(11.3 ± 2.1) [a]	(13.1 ± 2.5) [a]	(10.4 ± 3.5) [a]
(47 / 1004 Bouts had missing measurements)	5v5	33.0 ± N/A [A]	36.0 ± N/A [A]	—
		(10.7 ± 1.5) [a]	(11.0 ± 4.6) [a]	(—)
	7v7	39.5 ± 9.7 [A]	31.8 ± 8.2 [A]	38.4 ± 12.4 [A]
		(12.3 ± 3.5) [a]	(9.2 ± 2.8) [a]	(12.2 ± 4.2) [a]
Shapiro-Wilk Test: W = 1.00; *p* = 0.659. Levene's Test: F = 1.22; *p* = 0.208				
(Shapiro-Wilk Test: W = 0.96; *p* = <0.001. Levene's Test: F = 1.34; *p* = 0.022)				
HIdec	3v3	11.0 ± 5.0 [A]	15.2 ± 4.1 [A]	15.7 ± 8.1 [A]
16 / 305 SSGs had missing measurements		(3.3 ± 3.0) [a]	(5.1 ± 1.9) [a]	(5.0 ± 2.8) [a]
(47 / 1004 Bouts had missing measurements)	5v5	17.0 ± N/A [A]	13.0 ± N/A [A]	—
		(5.7 ± 2.1) [a]	(4.3 ± 1.2) [a]	(—)
	7v7	12.5 ± 5.2 [A]	10.8 ± 5.0 [A]	14.0 ± 8.5 [A]
		(3.8 ± 1.9) [a]	(3.1 ± 1.9) [a]	(4.6 ± 3.0) [a]
Shapiro-Wilk Test: W = 0.99; *p* = 0.258. Levene's Test: F = 0.98; *p* = 0.493				
(Shapiro-Wilk Test: W = 0.98; *p* = <0.001. Levene's Test: F = 0.93; *p* = 0.663)				
AL_{3D} (AU)	3v3	3.5 ± 0.5 [A]	4.0 ± 0.4 [A]	4.4 ± 0.9 [A]
13 / 305 SSGs had missing measurements		(4.3 ± 0.7) [ab]	(5.2 ± 0.9) [bc]	(5.7 ± 1.0) [c]
(44 / 1004 Bouts had missing measurements)	5v5	3.6 ± N/A [A]	4.6 ± N/A [A]	—
		(4.3 ± 0.3) [abc]	(4.8 ± 0.4) [abc]	(—)

U16		Small	Medium	Large
	7v7	3.4 ± 0.5 ^{A}	3.6 ± 0.7 ^{A}	4.1 ± 0.5 ^{A}
		(3.9 ± 0.5) ^{a}	(4.1 ± 0.8) ^{a}	(4.6 ± 0.7) ^{ab}
Shapiro-Wilk Test: W = 0.99; *p* = 0.007. Levene's Test: F = 0.71; *p* = 0.870				
(Shapiro-Wilk Test: W = 1.00; *p* = 0.004. Levene's Test: F = 1.08; *p* = 0.288)				
Impact (min^{-1})	3v3	0.0 ± 0.0 ^{A}	0.0 ± 0.0 ^{A}	0.0 ± 0.0 ^{A}
16 / 305 SSGs had missing measurements		(0.0 ± 0.1) ^{a}	(0.0 ± 0.1) ^{a}	(0.0 ± 0.1) ^{a}
(47 / 1004 Bouts had missing measurements)	5v5	0.0 ± N/A ^{A}	0.1 ± N/A ^{A}	—
		(0.0 ± 0.0) ^{a}	(0.1 ± 0.1) ^{a}	(—)
	7v7	0.1 ± 0.1 ^{A}	0.0 ± 0.1 ^{A}	0.0 ± 0.0 ^{A}
		(0.1 ± 0.2) ^{a}	(0.0 ± 0.1) ^{a}	(0.0 ± 0.1) ^{a}
Shapiro-Wilk Test: W = 0.78; *p* = <0.001. Levene's Test: F = 0.76; *p* = 0.806				
(Shapiro-Wilk Test: W = 0.58; *p* = <0.001. Levene's Test: F = 1.06; *p* = 0.342)				
HIRD (m)	3v3	68.0 ± 33.9 ^{ABC}	131.7 ± 58.1 ^{BC}	158.7 ± 53.2 ^{B}
30 / 305 SSGs had missing measurements		(22.0 ± 18.3) ^{abc}	(39.5 ± 29.5) ^{bc}	(49.9 ± 28.1) ^{c}
(101 / 1004 Bouts had missing measurements)	5v5	36.0 ± N/A ^{ABC}	27.0 ± N/A ^{ABC}	—
		(12.0 ± 10.6) ^{abc}	(8.7 ± 0.6) ^{ab}	(—)
	7v7	9.0 ± 7.8 ^{A}	52.0 ± 34.6 ^{ABC}	43.8 ± 21.9 ^{AC}
		(2.9 ± 3.2) ^{a}	(17.1 ± 13.2) ^{ab}	(14.0 ± 13.6) ^{a}
Shapiro-Wilk Test: W = 0.98; *p* = <0.001. Levene's Test: F = 2.16; *p* = <0.001				
(Shapiro-Wilk Test: W = 0.95; *p* = <0.001. Levene's Test: F = 2.51; *p* = <0.001)				
HSRD (m)	3v3	27.0 ± 17.0 ^{A}	74.0 ± 48.5 ^{A}	88.5 ± 45.4 ^{A}
30 / 305 SSGs had missing measurements		(9.2 ± 9.9) ^{abc}	(21.8 ± 22.4) ^{bc}	(28.2 ± 22.2) ^{b}
(101 / 1004 Bouts had missing measurements)	5v5	6.0 ± N/A ^{A}	1.0 ± N/A ^{A}	—
		(1.7 ± 1.5) ^{abc}	(0.3 ± 0.6) ^{abc}	(—)
	7v7	0.3 ± 0.6 ^{A}	21.7 ± 28.9 ^{A}	18.8 ± 15.7 ^{A}
		(0.1 ± 0.3) ^{a}	(7.1 ± 8.8) ^{abc}	(6.2 ± 8.7) ^{ac}
Shapiro-Wilk Test: W = 0.95; *p* = <0.001. Levene's Test: F = 4.31; *p* = <0.001				
(Shapiro-Wilk Test: W = 0.89; *p* = <0.001. Levene's Test: F = 2.95; *p* = <0.001)				
VHSRD (m)	3v3	0.5 ± 0.7 ^{A}	12.4 ± 17.9 ^{A}	11.0 ± 25.0 ^{A}
32 / 305 SSGs had missing measurements		(0.2 ± 0.4) ^{a}	(3.0 ± 8.1) ^{a}	(3.7 ± 9.3) ^{a}
(103 / 1004 Bouts had missing measurements)	5v5	0.0 ± N/A ^{A}	0.0 ± N/A ^{A}	—
		(0.0 ± 0.0) ^{a}	(0.0 ± 0.0) ^{a}	(—)
	7v7	0.0 ± 0.0 ^{A}	4.0 ± 6.9 ^{A}	2.0 ± 3.4 ^{A}
		(0.0 ± 0.0) ^{a}	(1.4 ± 3.3) ^{a}	(0.7 ± 2.0) ^{a}
Shapiro-Wilk Test: W = 0.66; *p* = <0.001. Levene's Test: F = 2.97; *p* = <0.001				
(Shapiro-Wilk Test: W = 0.58; *p* = <0.001. Levene's Test: F = 1.80; *p* = <0.001)				

Same grouping letter = not significantly different (H_0 not rejected at $p \leq 0.05$)

U18		Small	Medium	Large
TD (m)	3v3	1443.1 ± 192.2 ^{AB}	1507.3 ± 181.2 ^{ABC}	1693.6 ± 263.7 ^{C}
16 / 305 SSGs had missing measurements		(364.5 ± 51.5) ^{ab}	(409.1 ± 46.2) ^{cd}	(447.0 ± 61.8) ^{d}
(48 / 1004 Bouts had missing measurements)	5v5	1324.9 ± 204.5 ^{A}	1693.0 ± 97.9 ^{BC}	1670.3 ± 241.1 ^{C}
		(330.3 ± 56.6) ^{a}	(406.4 ± 38.5) ^{bcd}	(412.8 ± 73.3) ^{cd}
	7v7	1360.2 ± 65.8 ^{A}	1498.3 ± 131.4 ^{ABC}	1703.6 ± 143.8 ^{C}
		(329.3 ± 29.8) ^{a}	(371.2 ± 40.4) ^{abc}	(408.6 ± 42.4) ^{cd}

Shapiro-Wilk Test: W = 0.91; p = <0.001. Levene's Test: F = 1.42; p = 0.082
(Shapiro-Wilk Test: W = 0.67; p = <0.001. Levene's Test: F = 1.25; p = 0.065)

RD (m·min^{-1})	3v3	79.4 ± 11.0 ^{A}	83.8 ± 9.6 ^{ABC}	93.9 ± 14.9 ^{BC}
16 / 305 SSGs had missing measurements		(91.5 ± 12.7) ^{ab}	(102.4 ± 11.5) ^{d}	(111.5 ± 15.6) ^{f}
(47 / 1004 Bouts had missing measurements)	5v5	73.4 ± 11.3 ^{A}	87.7 ± 7.2 ^{ABC}	87.1 ± 13.0 ^{ABC}
		(81.4 ± 13.1) ^{ac}	(100.7 ± 9.8) ^{bdef}	(101.5 ± 17.7) ^{de}
	7v7	74.4 ± 3.7 ^{A}	80.3 ± 7.2 ^{AB}	94.3 ± 8.3 ^{C}
		(82.5 ± 7.3) ^{c}	(92.5 ± 9.7) ^{abce}	(102.3 ± 10.7) ^{d}

Shapiro-Wilk Test: W = 0.93; p = <0.001. Levene's Test: F = 1.49; p = 0.057
(Shapiro-Wilk Test: W = 0.99; p = <0.001. Levene's Test: F = 1.49; p = 0.003)

V_{AVG} (km·h^{-1})	3v3	4.8 ± 0.6 ^{A}	5.0 ± 0.6 ^{ABC}	5.6 ± 0.9 ^{BC}
16 / 305 SSGs had missing measurements		(5.5 ± 0.8) ^{ab}	(6.2 ± 0.7) ^{d}	(6.7 ± 0.9) ^{f}
(47 / 1004 Bouts had missing	5v5	4.4 ± 0.7 ^{A}	5.2 ± 0.4 ^{ABC}	5.2 ± 0.8 ^{ABC}
measurements)		(4.9 ± 0.8) ^{ac}	(6.0 ± 0.6) ^{bdef}	(6.1 ± 1.1) ^{de}
	7v7	4.5 ± 0.2 ^{A}	4.8 ± 0.4 ^{AB}	5.6 ± 0.5 ^{C}
		(4.9 ± 0.5) ^{c}	(5.6 ± 0.6) ^{abce}	(6.1 ± 0.6) ^{d}

Shapiro-Wilk Test: W = 0.93; p = <0.001. Levene's Test: F = 1.46; p = 0.065
(Shapiro-Wilk Test: W = 0.99; p = <0.001. Levene's Test: F = 1.48; p = 0.003)

V_{MAX} (km·h^{-1})	3v3	25.2 ± 3.2 ^{A}	25.8 ± 3.1 ^{A}	26.7 ± 2.8 ^{A}
16 / 305 SSGs had missing measurements		(22.6 ± 3.6) ^{a}	(23.7 ± 3.4) ^{ac}	(25.0 ± 3.2) ^{c}
(47 / 1004 Bouts had missing measurements)	5v5	23.2 ± 3.6 ^{AB}	26.9 ± 2.4 ^{A}	26.0 ± 4.2 ^{A}
		(21.0 ± 3.6) ^{ab}	(24.3 ± 3.4) ^{ac}	(23.1 ± 4.7) ^{ac}
	7v7	20.2 ± 1.4 ^{B}	27.0 ± 2.7 ^{A}	25.8 ± 4.0 ^{A}
		(18.8 ± 1.6) ^{b}	(23.8 ± 4.1) ^{ac}	(22.7 ± 3.9) ^{a}

Shapiro-Wilk Test: W = 0.95; p = <0.001. Levene's Test: F = 1.01; p = 0.454
(Shapiro-Wilk Test: W = 1.00; p = 0.011. Levene's Test: F = 1.23; p = 0.082)

HR_{AVG} (% HR_{MAX})	3v3	80.6 ± 5.7 ^{A}	82.0 ± 2.9 ^{A}	81.6 ± 4.1 ^{A}
48 / 305 SSGs had missing measurements		(82.7 ± 6.4) ^{ab}	(84.8 ± 3.6) ^{a}	(84.5 ± 4.7) ^{a}
(151 / 1004 Bouts had missing measurements)	5v5	74.4 ± 8.8 ^{A}	79.1 ± 4.5 ^{A}	76.6 ± 9.5 ^{A}
		(76.3 ± 9.8) ^{c}	(82.2 ± 5.0) ^{abc}	(79.7 ± 10.1) ^{bc}
	7v7	81.9 ± 3.0 ^{A}	81.6 ± 2.4 ^{A}	79.5 ± 7.4 ^{A}
		(85.1 ± 4.4) ^{a}	(84.7 ± 4.2) ^{a}	(81.3 ± 9.3) ^{abc}

Shapiro-Wilk Test: W = 0.96; p = <0.001. Levene's Test: F = 1.33; p = 0.129
(Shapiro-Wilk Test: W = 0.96; p = <0.001. Levene's Test: F = 1.24; p = 0.070)

HR_{MAX} (%HR_{MAX})	3v3	93.9 ± 4.9 ^{A}	94.2 ± 3.0 ^{A}	94.5 ± 3.6 ^{A}
48 / 305 SSGs had missing measurements		(91.1 ± 5.2) ^{ab}	(92.8 ± 3.9) ^{a}	(92.3 ± 4.3) ^{a}

U18		Small	Medium	Large
(151 / 1004 Bouts had missing measurements)	5v5	88.3 ± 4.7 [A]	91.1 ± 5.1 [A]	91.1 ± 8.9 [A]
		(84.7 ± 7.7) [c]	(90.4 ± 4.7) [abc]	(88.2 ± 10.3) [bc]
	7v7	94.6 ± 2.8 [A]	94.7 ± 3.1 [A]	92.7 ± 6.6 [A]
		(92.1 ± 4.2) [ab]	(92.3 ± 3.9) [ab]	(89.5 ± 8.7) [abc]

Shapiro-Wilk Test: W = 0.93; *p* = <0.001. Levene's Test: F = 0.86; *p* = 0.682
(Shapiro-Wilk Test: W = 0.92; *p* = <0.001. Levene's Test: F = 0.98; *p* = 0.530)

RPE (6-20)	3v3	13.9 ± 2.9 [AB]	15.0 ± 1.6 [AD]	16.1 ± 1.6 [D]
3 / 305 SSGs had missing measurements		(13.4 ± 2.4) [ab]	(14.2 ± 2.2) [ae]	(15.0 ± 1.8) [e]
(2 / 1004 Bouts had missing measurements)	5v5	12.9 ± 0.9 [ABC]	13.9 ± 1.1 [ABCD]	13.1 ± 3.0 [ABC]
		(11.9 ± 1.6) [c]	(12.1 ± 2.1) [bc]	(11.6 ± 3.2) [c]
	7v7	11.5 ± 0.8 [C]	13.7 ± 1.2 [ABCD]	12.5 ± 1.5 [BC]
		(10.0 ± 1.7) [d]	(12.6 ± 1.6) [bc]	(12.3 ± 1.6) [c]

Shapiro-Wilk Test: W = 0.98; *p* = 0.001. Levene's Test: F = 2.35; *p* = <0.001
(Shapiro-Wilk Test: W = 0.99; *p* = <0.001. Levene's Test: F = 1.95; *p* = <0.001)

Sprint·min^{-1}	3v3	2.1 ± 1.0 [A]	2.2 ± 0.4 [A]	2.2 ± 0.4 [A]
16 / 305 SSGs had missing measurements		(2.9 ± 1.4) [a]	(3.2 ± 0.7) [a]	(3.0 ± 1.0) [a]
(47 / 1004 Bouts had missing measurements)	5v5	1.9 ± 0.6 [A]	2.3 ± 0.2 [A]	1.9 ± 0.9 [A]
		(2.7 ± 1.0) [a]	(2.9 ± 1.2) [a]	(2.5 ± 1.4) [a]
	7v7	2.0 ± 0.4 [A]	2.2 ± 0.4 [A]	2.2 ± 0.6 [A]
		(2.7 ± 0.7) [a]	(3.0 ± 0.9) [a]	(3.0 ± 1.0) [a]

Shapiro-Wilk Test: W = 0.97; *p* = <0.001. Levene's Test: F = 2.55; *p* = <0.001
(Shapiro-Wilk Test: W = 0.99; *p* = <0.001. Levene's Test: F = 1.73; *p* = <0.001)

HIacc	3v3	40.2 ± 14.2 [A]	30.7 ± 10.2 [AB]	28.2 ± 8.5 [B]
16 / 305 SSGs had missing measurements		(12.9 ± 5.0) [a]	(10.0 ± 4.1) [b]	(9.4 ± 3.5) [b]
(47 / 1004 Bouts had missing measurements)	5v5	35.4 ± 11.8 [AB]	35.8 ± 6.0 [AB]	31.3 ± 15.5 [AB]
		(11.6 ± 5.0) [ab]	(11.6 ± 3.1) [ab]	(9.6 ± 5.2) [b]
	7v7	33.5 ± 5.7 [AB]	32.3 ± 9.0 [AB]	30.8 ± 8.8 [AB]
		(10.4 ± 3.1) [ab]	(9.8 ± 3.9) [b]	(9.5 ± 4.4) [b]

Shapiro-Wilk Test: W = 1.00; *p* = 0.659. Levene's Test: F = 1.22; *p* = 0.208
(Shapiro-Wilk Test: W = 0.96; *p* = <0.001. Levene's Test: F = 1.34; *p* = 0.022)

HIdec	3v3	13.6 ± 5.9 [A]	11.7 ± 4.0 [A]	10.7 ± 4.5 [A]
16 / 305 SSGs had missing measurements		(4.4 ± 2.1) [a]	(3.8 ± 1.8) [ab]	(3.5 ± 2.1) [ab]
(47 / 1004 Bouts had missing measurements)	5v5	12.3 ± 6.2 [A]	11.8 ± 4.4 [A]	10.7 ± 5.5 [A]
		(4.1 ± 2.3) [ab]	(3.9 ± 2.1) [ab]	(3.4 ± 2.1) [ab]
	7v7	11.4 ± 4.5 [A]	12.8 ± 4.0 [A]	10.2 ± 4.9 [A]
		(3.5 ± 1.9) [ab]	(3.9 ± 1.7) [ab]	(3.2 ± 2.1) [b]

Shapiro-Wilk Test: W = 0.99; *p* = 0.258. Levene's Test: F = 0.98; *p* = 0.493
(Shapiro-Wilk Test: W = 0.98; *p* = <0.001. Levene's Test: F = 0.93; *p* = 0.663)

AL_{3D} (AU)	3v3	3.6 ± 0.8 [AB]	3.7 ± 0.6 [AB]	4.1 ± 0.8 [B]
13 / 305 SSGs had missing measurements		(4.2 ± 0.9) [abc]	(4.7 ± 0.9) [cd]	(5.2 ± 1.1) [d]
(44 / 1004 Bouts had missing measurements)	5v5	2.9 ± 0.6 [A]	3.9 ± 0.6 [AB]	3.5 ± 0.8 [AB]
		(3.6 ± 0.8) [a]	(4.6 ± 0.9) [cd]	(4.3 ± 1.2) [abc]

U18		Small	Medium	Large
	7v7	3.4 ± 0.4 AB	3.4 ± 0.7 AB	4.0 ± 0.7 B
		(3.8 ± 0.5) ab	(4.1 ± 0.8) abc	(4.4 ± 0.8) bc
Shapiro-Wilk Test: W = 0.99; *p* = 0.007. Levene's Test: F = 0.71; *p* = 0.870				
(Shapiro-Wilk Test: W = 1.00; *p* = 0.004. Levene's Test: F = 1.08; *p* = 0.288)				
Impact (min^{-1})	3v3	0.0 ± 0.0 A	0.0 ± 0.0 A	0.0 ± 0.0 A
16 / 305 SSGs had missing measurements		(0.0 ± 0.1) a	(0.0 ± 0.1) a	(0.0 ± 0.1) a
(47 / 1004 Bouts had missing measurements)	5v5	0.0 ± 0.0 A	0.0 ± 0.0 A	0.0 ± 0.0 A
		(0.0 ± 0.0) a	(0.0 ± 0.1) a	(0.0 ± 0.0) a
	7v7	0.0 ± 0.0 A	0.0 ± 0.0 A	0.0 ± 0.0 A
		(0.0 ± 0.1) a	(0.0 ± 0.1) a	(0.0 ± 0.1) a
Shapiro-Wilk Test: W = 0.78; *p* = <0.001. Levene's Test: F = 0.76; *p* = 0.806				
(Shapiro-Wilk Test: W = 0.58; *p* = <0.001. Levene's Test: F = 1.06; *p* = 0.342)				
HIRD (m)	3v3	57.6 ± 37.7 AB	107.9 ± 62.9 BC	153.2 ± 73.1 C
30 / 305 SSGs had missing measurements		(18.6 ± 15.3) a	(35.0 ± 25.9) c	(50.1 ± 29.4) d
(101 / 1004 Bouts had missing measurements)	5v5	40.7 ± 25.7 AB	78.2 ± 57.3 ABC	98.2 ± 66.0 BC
		(13.5 ± 11.8) ab	(29.4 ± 23.5) ac	(32.1 ± 27.8) c
	7v7	10.2 ± 9.5 A	83.5 ± 51.2 B	69.4 ± 48.6 AB
		(3.1 ± 3.8) b	(27.2 ± 22.4) ac	(22.5 ± 22.5) ac
Shapiro-Wilk Test: W = 0.98; *p* = <0.001. Levene's Test: F = 2.16; *p* = <0.001				
(Shapiro-Wilk Test: W = 0.95; *p* = <0.001. Levene's Test: F = 2.51; *p* = <0.001)				
HSRD (m)	3v3	28.7 ± 21.5 AB	66.4 ± 50.5 BC	94.9 ± 56.5 C
30 / 305 SSGs had missing measurements		(9.4 ± 10.3) ab	(21.8 ± 22.3) cd	(31.0 ± 21.9) c
(101 / 1004 Bouts had missing measurements)	5v5	22.0 ± 15.2 AB	50.5 ± 46.8 ABC	63.4 ± 53.1 BC
		(7.3 ± 8.7) ab	(18.9 ± 18.6) bcd	(21.1 ± 22.7) cd
	7v7	1.8 ± 2.6 A	57.9 ± 43.8 ABC	40.9 ± 37.3 AB
		(0.5 ± 1.1) a	(19.2 ± 19.9) bcd	(13.5 ± 18.2) bd
Shapiro-Wilk Test: W = 0.95; *p* = <0.001. Levene's Test: F = 4.31; *p* = <0.001				
(Shapiro-Wilk Test: W = 0.89; *p* = <0.001. Levene's Test: F = 2.95; *p* = <0.001)				
VHSRD (m)	3v3	4.0 ± 8.1 A	13.4 ± 17.4 A	17.5 ± 19.6 A
32 / 305 SSGs had missing measurements		(1.3 ± 4.6) a	(5.0 ± 9.8) a	(5.7 ± 8.5) a
(103 / 1004 Bouts had missing measurements)	5v5	0.6 ± 0.5 A	18.2 ± 28.5 A	15.7 ± 21.9 A
		(0.2 ± 0.4) a	(6.8 ± 10.9) a	(5.4 ± 10.4) a
	7v7	0.0 ± 0.0 A	19.3 ± 23.8 A	10.1 ± 12.6 A
		(0.0 ± 0.0) a	(6.4 ± 11.8) a	(3.3 ± 7.5) a
Shapiro-Wilk Test: W = 0.66; *p* = <0.001. Levene's Test: F = 2.97; *p* = <0.001				
(Shapiro-Wilk Test: W = 0.58; *p* = <0.001. Levene's Test: F = 1.80; *p* = <0.001)				

Same grouping letter = not significantly different (H_0 not rejected at $p \leq 0.05$)

Appendix 11: Youth SSG relative speed zones (imputed values - R)

Table I: 5 relative speed zones (%V_{TOP})

Youth		Small	Medium	Large
V_{Z1} (m)	3v3	694.3 ± 69.2 ^{A}	671.0 ± 79.3 ^{A}	658.2 ± 83.2 ^{A}
30 / 305 SSGs had missing measurements		(155.6 ± 18.5) ^{abc}	(152.5 ± 24.4) ^{abc}	(146.5 ± 26.7) ^{b}
(101 / 1004 Bouts had missing measurements)	5v5	676.8 ± 89.3 ^{A}	695.4 ± 119.5 ^{A}	688.2 ± 117.2 ^{A}
		(160.8 ± 18.3) ^{a}	(162.6 ± 20.8) ^{a}	(157.5 ± 26.5) ^{abc}
	7v7	700.8 ± 83.2 ^{A}	653.0 ± 108.0 ^{A}	679.3 ± 96.1 ^{A}
		(161.4 ± 19.4) ^{a}	(149.7 ± 29.8) ^{bc}	(156.5 ± 26.9) ^{ac}
Shapiro-Wilk Test: W = 0.98; *p* = 0.001. Levene's Test: F = 0.82; *p* = 0.587				
(Shapiro-Wilk Test: W = 0.99; *p* = <0.001. Levene's Test: F = 2.10; *p* = 0.001)				
V_{Z2} (m)	3v3	697.9 ± 211.0 ^{ABCD}	689.2 ± 157.6 ^{ABC}	786.1 ± 234.9 ^{CD}
30 / 305 SSGs had missing measurements		(180.8 ± 53.7) ^{ab}	(188.0 ± 54.7) ^{abd}	(207.9 ± 67.2) ^{d}
(101 / 1004 Bouts had missing measurements)	5v5	534.0 ± 136.3 ^{AE}	632.9 ± 224.2 ^{ABCE}	729.2 ± 213.1 ^{BCD}
		(141.7 ± 45.2) ^{c}	(180.2 ± 45.8) ^{abd}	(202.6 ± 67.2) ^{bd}
	7v7	531.2 ± 157.7 ^{E}	623.1 ± 161.4 ^{ABE}	828.5 ± 197.7 ^{D}
		(137.7 ± 37.8) ^{c}	(177.0 ± 59.5) ^{a}	(195.5 ± 61.8) ^{abd}
Shapiro-Wilk Test: W = 0.99; *p* = 0.215. Levene's Test: F = 1.39; *p* = 0.200				
(Shapiro-Wilk Test: W = 1.00; *p* = 0.679. Levene's Test: F = 2.45; *p* = <0.001)				
V_{Z3} (m)	3v3	99.3 ± 52.9 ^{ABC}	183.6 ± 68.9 ^{DE}	217.5 ± 76.6 ^{D}
30 / 305 SSGs had missing measurements		(30.8 ± 21.1) ^{a}	(55.8 ± 29.4) ^{c}	(68.2 ± 35.1) ^{f}
(101 / 1004 Bouts had missing measurements)	5v5	63.4 ± 30.7 ^{AB}	105.5 ± 36.3 ^{ABCF}	162.8 ± 76.8 ^{EF}
		(21.0 ± 16.1) ^{ab}	(35.4 ± 17.2) ^{ad}	(52.6 ± 31.3) ^{ce}
	7v7	55.3 ± 34.3 ^{A}	138.7 ± 85.1 ^{CF}	110.5 ± 45.2 ^{BC}
		(15.3 ± 12.7) ^{b}	(42.3 ± 30.8) ^{de}	(32.3 ± 22.0) ^{a}
Shapiro-Wilk Test: W = 0.99; *p* = 0.177. Levene's Test: F = 5.23; *p* = <0.001				
(Shapiro-Wilk Test: W = 0.98; *p* = <0.001. Levene's Test: F = 5.31; *p* = <0.001)				
V_{Z4} (m)	3v3	2.9 ± 5.7 ^{AB}	12.1 ± 12.3 ^{BC}	16.7 ± 18.2 ^{C}
30 / 305 SSGs had missing measurements		(0.9 ± 3.0) ^{a}	(3.8 ± 6.9) ^{bc}	(5.1 ± 8.4) ^{b}
(101 / 1004 Bouts had missing measurements)	5v5	0.8 ± 2.6 ^{AB}	6.6 ± 12.9 ^{ABC}	13.8 ± 17.4 ^{C}
		(0.3 ± 1.5) ^{a}	(2.1 ± 5.4) ^{abc}	(4.7 ± 9.2) ^{bc}
	7v7	1.3 ± 3.0 ^{A}	9.8 ± 15.4 ^{ABC}	7.1 ± 10.9 ^{ABC}
		(0.3 ± 1.2) ^{a}	(3.5 ± 7.2) ^{bc}	(2.1 ± 5.5) ^{ac}
Shapiro-Wilk Test: W = 0.86; *p* = <0.001. Levene's Test: F = 5.76; *p* = <0.001				
(Shapiro-Wilk Test: W = 0.69; *p* = <0.001. Levene's Test: F = 3.03; *p* = <0.001)				
V_{Z5} (m)	3v3	0.1 ± 0.5 ^{A}	0.3 ± 1.2 ^{AB}	1.8 ± 5.7 ^{B}
30 / 305 SSGs had missing measurements		(0.0 ± 0.2) ^{a}	(0.1 ± 0.7) ^{ab}	(0.5 ± 3.2) ^{b}
(101 / 1004 Bouts had missing measurements)	5v5	0.0 ± 0.0 ^{AB}	0.0 ± 0.0 ^{AB}	0.4 ± 0.8 ^{AB}
		(0.0 ± 0.2) ^{ab}	(0.0 ± 0.0) ^{ab}	(0.1 ± 0.5) ^{ab}
	7v7	0.1 ± 0.4 ^{AB}	0.5 ± 1.3 ^{AB}	0.4 ± 1.1 ^{AB}
		(0.0 ± 0.2) ^{ab}	(0.2 ± 0.7) ^{ab}	(0.1 ± 0.6) ^{ab}
Shapiro-Wilk Test: W = 0.33; *p* = <0.001. Levene's Test: F = 2.01; *p* = 0.046				
(Shapiro-Wilk Test: W = 0.18; *p* = <0.001. Levene's Test: F = 1.82; *p* = 0.008)				

<20% (z1), 20-50% (z2), 51-80% (z3), 81-95% (z4), 96-100% (z5) V_{TOP}; *Same grouping letter = not significantly different (H_0 not rejected at $p \leq 0.05$)*

U14		Small	Medium	Large
V_{Z1} (m)	3v3	649.0 ± 57.8 [A]	700.4 ± 100.2 [A]	752.7 ± 70.2 [A]
30 / 305 SSGs had missing measurements		(153.7 ± 21.8) [a]	(160.8 ± 23.5) [a]	(166.9 ± 35.1) [a]
(101 / 1004 Bouts had missing	5v5	—	714.9 ± 62.2 [A]	—
measurements)		(158.6 ± 16.1) [a]	(166.9 ± 19.8) [a]	(—)
	7v7	—	736.0 ± 104.5 [A]	—
		(—)	(170.2 ± 43.4) [a]	(169.6 ± 25.4) [a]
Shapiro-Wilk Test: W = 0.99; *p* = 0.010. Levene's Test: F = 0.90; *p* = 0.613				
(Shapiro-Wilk Test: W = 0.99; *p* = <0.001. Levene's Test: F = 0.99; *p* = 0.501)				
V_{Z2} (m)	3v3	736.4 ± 142.9 [A]	636.7 ± 149.5 [AB]	607.2 ± 167.6 [AB]
30 / 305 SSGs had missing measurements		(187.8 ± 68.5) [a]	(166.1 ± 56.2) [ac]	(168.5 ± 63.1) [ac]
(101 / 1004 Bouts had missing	5v5	—	518.1 ± 91.7 [AB]	—
measurements)		(110.5 ± 31.2) [b]	(157.3 ± 39.3) [ac]	(—)
	7v7	—	429.9 ± 153.6 [B]	—
		(—)	(105.7 ± 53.5) [b]	(134.7 ± 52.8) [bc]
Shapiro-Wilk Test: W = 0.99; *p* = 0.132. Levene's Test: F = 1.11; *p* = 0.321				
(Shapiro-Wilk Test: W = 1.00; *p* = 0.028. Levene's Test: F = 1.77; *p* = <0.001)				
V_{Z3} (m)	3v3	53.4 ± 20.7 [A]	157.7 ± 70.9 [B]	139.3 ± 91.3 [AB]
30 / 305 SSGs had missing measurements		(17.7 ± 15.0) [a]	(45.9 ± 27.7) [c]	(42.1 ± 33.8) [bc]
(101 / 1004 Bouts had missing	5v5	—	107.6 ± 34.2 [AB]	—
measurements)		(21.3 ± 17.2) [ab]	(33.8 ± 17.3) [abc]	(—)
	7v7	—	61.5 ± 62.8 [A]	—
		(—)	(15.3 ± 19.6) [a]	(20.7 ± 13.9) [a]
Shapiro-Wilk Test: W = 0.99; *p* = 0.118. Levene's Test: F = 1.69; *p* = 0.019				
(Shapiro-Wilk Test: W = 0.99; *p* = <0.001. Levene's Test: F = 1.76; *p* = <0.001)				
V_{Z4} (m)	3v3	1.8 ± 4.0 [A]	9.4 ± 9.7 [A]	14.3 ± 20.3 [A]
30 / 305 SSGs had missing measurements		(0.5 ± 1.9) [a]	(2.6 ± 4.8) [a]	(4.0 ± 8.6) [a]
(101 / 1004 Bouts had missing	5v5	—	3.9 ± 5.1 [A]	—
measurements)		(0.5 ± 1.6) [a]	(0.9 ± 2.7) [a]	(—)
	7v7	—	0.4 ± 1.1 [A]	—
		(—)	(0.1 ± 0.6) [a]	(1.4 ± 3.6) [a]
Shapiro-Wilk Test: W = 0.89; *p* = <0.001. Levene's Test: F = 2.08; *p* = 0.002				
(Shapiro-Wilk Test: W = 0.75; *p* = <0.001. Levene's Test: F = 1.50; *p* = 0.002)				
V_{Z5} (m)	3v3	0.0 ± 0.0 [A]	0.3 ± 0.7 [A]	5.2 ± 11.7 [B]
30 / 305 SSGs had missing measurements		(0.0 ± 0.0) [a]	(0.1 ± 0.4) [a]	(1.4 ± 6.2) [b]
(101 / 1004 Bouts had missing	5v5	—	0.0 ± 0.0 [A]	—
measurements)		(0.1 ± 0.4) [a]	(0.0 ± 0.0) [a]	(—)
	7v7	—	0.0 ± 0.0 [A]	—
		(—)	(0.0 ± 0.0) [a]	(0.0 ± 0.0) [a]
Shapiro-Wilk Test: W = 0.39; *p* = <0.001. Levene's Test: F = 1.84; *p* = 0.007				
(Shapiro-Wilk Test: W = 0.21; *p* = <0.001. Levene's Test: F = 1.69; *p* = <0.001)				

<20% (z1), 20-50% (z2), 51-80% (z3), 81-95% (z4), 96-100% (z5) V_{TOP}; *Same grouping letter = not significantly different (H_0 not rejected at $p \leq 0.05$)*

U15		Small	Medium	Large
V_{Z1} (m)	3v3	655.0 ± 95.9 [AB]	695.5 ± 73.4 [AB]	650.4 ± 82.2 [AB]
30 / 305 SSGs had missing measurements		(150.5 ± 16.7) [ab]	(168.4 ± 25.5) [a]	(153.5 ± 29.5) [ab]
(101 / 1004 Bouts had missing	5v5	666.1 ± 102.0 [AB]	—	634.2 ± 88.7 [AB]
measurements)		(159.5 ± 21.0) [a]	(—)	(153.7 ± 29.5) [ab]
	7v7	719.8 ± 70.5 [A]	595.0 ± 89.4 [B]	675.7 ± 90.7 [AB]
		(166.3 ± 20.3) [a]	(141.0 ± 26.4) [b]	(157.2 ± 25.2) [a]
Shapiro-Wilk Test: W = 0.99; *p* = 0.010. Levene's Test: F = 0.90; *p* = 0.613				
(Shapiro-Wilk Test: W = 0.99; *p* = <0.001. Levene's Test: F = 0.99; *p* = 0.501)				
V_{Z2} (m)	3v3	998.6 ± 254.2 [A]	769.5 ± 173.8 [ADE]	925.8 ± 169.8 [AE]
30 / 305 SSGs had missing measurements		(201.9 ± 52.0) [ab]	(153.1 ± 49.2) [ac]	(183.0 ± 68.4) [ab]
(101 / 1004 Bouts had missing	5v5	491.2 ± 125.1 [BC]	—	672.6 ± 186.1 [CDE]
measurements)		(156.7 ± 48.9) [a]	(—)	(208.5 ± 63.2) [b]
	7v7	420.2 ± 93.5 [B]	656.2 ± 127.1 [CD]	704.8 ± 115.0 [CDE]
		(112.8 ± 27.6) [c]	(200.8 ± 51.6) [b]	(200.2 ± 44.6) [b]
Shapiro-Wilk Test: W = 0.99; *p* = 0.132. Levene's Test: F = 1.11; *p* = 0.321				
(Shapiro-Wilk Test: W = 1.00; *p* = 0.028. Levene's Test: F = 1.77; *p* = <0.001)				
V_{Z3} (m)	3v3	126.4 ± 64.3 [ABCD]	149.7 ± 101.9 [BCD]	175.4 ± 35.2 [CD]
30 / 305 SSGs had missing measurements		(42.1 ± 26.7) [ab]	(47.4 ± 32.9) [ab]	(51.9 ± 22.5) [ab]
(101 / 1004 Bouts had missing	5v5	55.5 ± 24.6 [A]	—	199.1 ± 65.8 [C]
measurements)		(18.2 ± 14.4) [c]	(—)	(64.7 ± 30.5) [a]
	7v7	70.3 ± 38.2 [AB]	176.8 ± 89.1 [C]	99.3 ± 37.4 [ABD]
		(18.4 ± 15.0) [c]	(53.9 ± 32.5) [a]	(31.4 ± 17.8) [bc]
Shapiro-Wilk Test: W = 0.99; *p* = 0.118. Levene's Test: F = 1.69; *p* = 0.019				
(Shapiro-Wilk Test: W = 0.99; *p* = <0.001. Levene's Test: F = 1.76; *p* = <0.001)				
V_{Z4} (m)	3v3	3.0 ± 2.7 [AB]	10.8 ± 16.5 [AB]	26.2 ± 25.1 [B]
30 / 305 SSGs had missing measurements		(1.0 ± 2.1) [ab]	(3.7 ± 6.5) [ab]	(7.6 ± 11.6) [b]
(101 / 1004 Bouts had missing	5v5	1.3 ± 3.5 [A]	—	10.6 ± 14.1 [AB]
measurements)		(0.4 ± 2.0) [a]	(—)	(3.5 ± 7.1) [ab]
	7v7	2.5 ± 4.0 [A]	9.9 ± 13.2 [AB]	6.4 ± 10.7 [AB]
		(0.6 ± 1.7) [a]	(3.6 ± 6.3) [ab]	(2.2 ± 5.0) [ab]
Shapiro-Wilk Test: W = 0.89; *p* = <0.001. Levene's Test: F = 2.08; *p* = 0.002				
(Shapiro-Wilk Test: W = 0.75; *p* = <0.001. Levene's Test: F = 1.50; *p* = 0.002)				
V_{Z5} (m)	3v3	0.0 ± 0.0 [A]	0.0 ± 0.0 [A]	4.2 ± 6.6 [B]
30 / 305 SSGs had missing measurements		(0.0 ± 0.0) [ab]	(0.0 ± 0.0) [ab]	(1.2 ± 3.2) [b]
(101 / 1004 Bouts had missing	5v5	0.0 ± 0.0 [A]	—	0.6 ± 1.1 [A]
measurements)		(0.0 ± 0.0) [a]	(—)	(0.2 ± 0.7) [ab]
	7v7	0.2 ± 0.6 [A]	0.6 ± 1.2 [A]	0.6 ± 1.7 [A]
		(0.1 ± 0.3) [a]	(0.2 ± 0.6) [a]	(0.2 ± 1.0) [ab]
Shapiro-Wilk Test: W = 0.39; *p* = <0.001. Levene's Test: F = 1.84; *p* = 0.007				
(Shapiro-Wilk Test: W = 0.21; *p* = <0.001. Levene's Test: F = 1.69; *p* = <0.001)				

<20% (z1), 20-50% (z2), 51-80% (z3), 81-95% (z4), 96-100% (z5) V_{TOP}; *Same grouping letter = not significantly different (H_0 not rejected at $p \leq 0.05$)*

U16		Small	Medium	Large
V_{Z1} (m)	3v3	726.0 ± 55.2 [A]	668.4 ± 48.7 [A]	640.3 ± 37.2 [A]
30 / 305 SSGs had missing measurements		(160.5 ± 17.7) [a]	(144.2 ± 16.4) [a]	(136.0 ± 18.3) [a]
(101 / 1004 Bouts had missing	5v5	651.0 ± N/A [A]	681.0 ± N/A [A]	—
measurements)		(159.7 ± 4.0) [a]	(148.0 ± 5.6) [a]	(—)
	7v7	742.3 ± 45.4 [A]	787.0 ± 77.5 [A]	702.2 ± 79.8 [A]
		(164.1 ± 12.8) [a]	(162.8 ± 10.1) [a]	(159.2 ± 25.2) [a]
Shapiro-Wilk Test: W = 0.99; *p* = 0.010. Levene's Test: F = 0.90; *p* = 0.613				
(Shapiro-Wilk Test: W = 0.99; *p* = <0.001. Levene's Test: F = 0.99; *p* = 0.501)				
V_{Z2} (m)	3v3	613.0 ± 75.0 [A]	731.1 ± 129.8 [A]	794.8 ± 234.7 [A]
30 / 305 SSGs had missing measurements		(182.5 ± 34.3) [ab]	(220.0 ± 39.7) [ab]	(234.5 ± 70.1) [b]
(101 / 1004 Bouts had missing	5v5	756.0 ± N/A [A]	1068.0 ± N/A [A]	—
measurements)		(187.7 ± 4.5) [ab]	(243.0 ± 17.0) [ab]	(—)
	7v7	604.7 ± 119.3 [A]	719.0 ± 142.2 [A]	968.5 ± 227.4 [A]
		(164.0 ± 37.3) [a]	(173.4 ± 44.8) [ab]	(233.5 ± 73.1) [b]
Shapiro-Wilk Test: W = 0.99; *p* = 0.132. Levene's Test: F = 1.11; *p* = 0.321				
(Shapiro-Wilk Test: W = 1.00; *p* = 0.028. Levene's Test: F = 1.77; *p* = <0.001)				
V_{Z3} (m)	3v3	132.0 ± 65.1 [AB]	230.7 ± 54.7 [B]	276.7 ± 35.1 [B]
30 / 305 SSGs had missing measurements		(43.0 ± 27.1) [ab]	(71.4 ± 33.7) [bc]	(88.0 ± 31.2) [c]
(101 / 1004 Bouts had missing	5v5	131.0 ± N/A [AB]	102.0 ± N/A [AB]	—
measurements)		(43.7 ± 30.9) [abc]	(34.3 ± 2.1) [ab]	(—)
	7v7	32.7 ± 18.6 [A]	91.7 ± 40.4 [A]	99.8 ± 41.1 [A]
		(9.3 ± 7.3) [a]	(29.3 ± 17.3) [a]	(30.8 ± 24.0) [a]
Shapiro-Wilk Test: W = 0.99; *p* = 0.118. Levene's Test: F = 1.69; *p* = 0.019				
(Shapiro-Wilk Test: W = 0.99; *p* = <0.001. Levene's Test: F = 1.76; *p* = <0.001)				
V_{Z4} (m)	3v3	1.0 ± 1.4 [A]	13.4 ± 13.0 [A]	12.2 ± 18.6 [A]
30 / 305 SSGs had missing measurements		(0.3 ± 0.8) [a]	(3.5 ± 6.7) [a]	(4.1 ± 7.5) [a]
(101 / 1004 Bouts had missing	5v5	0.0 ± N/A [A]	0.0 ± N/A [A]	—
measurements)		(0.0 ± 0.0) [a]	(0.0 ± 0.0) [a]	(—)
	7v7	0.0 ± 0.0 [A]	2.3 ± 4.0 [A]	2.0 ± 4.0 [A]
		(0.0 ± 0.0) [a]	(0.8 ± 2.3) [a]	(0.7 ± 2.3) [a]
Shapiro-Wilk Test: W = 0.89; *p* = <0.001. Levene's Test: F = 2.08; *p* = 0.002				
(Shapiro-Wilk Test: W = 0.75; *p* = <0.001. Levene's Test: F = 1.50; *p* = 0.002)				
V_{Z5} (m)	3v3	0.0 ± 0.0 [A]	0.1 ± 0.3 [A]	0.5 ± 0.8 [A]
30 / 305 SSGs had missing measurements		(0.0 ± 0.0) [a]	(0.0 ± 0.2) [a]	(0.2 ± 0.5) [a]
(101 / 1004 Bouts had missing	5v5	0.0 ± N/A [A]	0.0 ± N/A [A]	—
measurements)		(0.0 ± 0.0) [a]	(0.0 ± 0.0) [a]	(—)
	7v7	0.0 ± 0.0 [A]	0.0 ± 0.0 [A]	0.5 ± 1.0 [A]
		(0.0 ± 0.0) [a]	(0.0 ± 0.0) [a]	(0.2 ± 0.6) [a]
Shapiro-Wilk Test: W = 0.39; *p* = <0.001. Levene's Test: F = 1.84; *p* = 0.007				
(Shapiro-Wilk Test: W = 0.21; *p* = <0.001. Levene's Test: F = 1.69; *p* = <0.001)				

<20% (z1), 20-50% (z2), 51-80% (z3), 81-95% (z4), 96-100% (z5) V_{TOP}; *Same grouping letter = not significantly different (H_0 not rejected at $p \leq 0.05$)*

U18		Small	Medium	Large
V_{Z1} (m)	3v3	710.0 ± 61.7 [A]	645.1 ± 80.7 [A]	630.3 ± 79.4 [A]
30 / 305 SSGs had missing measurements		(157.0 ± 17.6) [ab]	(144.3 ± 23.7) [bc]	(138.4 ± 16.6) [c]
(101 / 1004 Bouts had missing	5v5	695.9 ± 79.0 [A]	665.3 ± 192.0 [A]	718.3 ± 122.4 [A]
measurements)		(165.0 ± 17.8) [a]	(157.2 ± 22.6) [abc]	(159.6 ± 24.6) [a]
	7v7	663.6 ± 97.5 [A]	685.5 ± 67.7 [A]	676.8 ± 106.7 [A]
		(154.4 ± 18.1) [abc]	(151.4 ± 17.2) [abc]	(148.8 ± 27.1) [abc]
Shapiro-Wilk Test: W = 0.99; *p* = 0.010. Levene's Test: F = 0.90; *p* = 0.613				
(Shapiro-Wilk Test: W = 0.99; *p* = <0.001. Levene's Test: F = 0.99; *p* = 0.501)				
V_{Z2} (m)	3v3	631.6 ± 164.2 [AB]	663.5 ± 166.8 [AB]	807.5 ± 251.1 [BC]
30 / 305 SSGs had missing measurements		(173.2 ± 48.1) [ab]	(201.2 ± 49.2) [bc]	(225.0 ± 57.3) [c]
(101 / 1004 Bouts had missing	5v5	563.4 ± 129.8 [A]	751.8 ± 253.9 [ABC]	760.7 ± 225.5 [ABC]
measurements)		(143.3 ± 37.6) [a]	(211.4 ± 28.5) [bc]	(199.2 ± 69.7) [bc]
	7v7	653.6 ± 134.3 [AB]	669.4 ± 147.1 [AB]	886.7 ± 199.5 [C]
		(161.4 ± 28.0) [a]	(174.8 ± 37.8) [ab]	(214.5 ± 54.1) [c]
Shapiro-Wilk Test: W = 0.99; *p* = 0.132. Levene's Test: F = 1.11; *p* = 0.321				
(Shapiro-Wilk Test: W = 1.00; *p* = 0.028. Levene's Test: F = 1.77; *p* = <0.001)				
V_{Z3} (m)	3v3	100.5 ± 50.6 [AB]	184.6 ± 47.5 [CD]	239.1 ± 62.9 [D]
30 / 305 SSGs had missing measurements		(32.3 ± 18.9) [ab]	(58.2 ± 22.6) [d]	(78.6 ± 31.7) [e]
(101 / 1004 Bouts had missing	5v5	65.1 ± 29.7 [AB]	102.5 ± 45.7 [ABC]	142.6 ± 76.6 [BC]
measurements)		(21.5 ± 13.5) [ac]	(38.5 ± 18.8) [abd]	(45.8 ± 29.9) [bd]
	7v7	42.5 ± 24.0 [A]	123.1 ± 39.1 [ABC]	120.9 ± 50.7 [B]
		(13.1 ± 9.6) [c]	(38.2 ± 19.0) [ab]	(38.9 ± 25.2) [ab]
Shapiro-Wilk Test: W = 0.99; *p* = 0.118. Levene's Test: F = 1.69; *p* = 0.019				
(Shapiro-Wilk Test: W = 0.99; *p* = <0.001. Levene's Test: F = 1.76; *p* = <0.001)				
V_{Z4} (m)	3v3	3.3 ± 6.8 [AB]	13.3 ± 12.5 [ABC]	16.3 ± 15.5 [BC]
30 / 305 SSGs had missing measurements		(1.1 ± 3.6) [a]	(5.0 ± 8.4) [bc]	(5.3 ± 7.5) [c]
(101 / 1004 Bouts had missing	5v5	0.1 ± 0.4 [ABC]	12.3 ± 20.6 [ABC]	15.6 ± 19.1 [ABC]
measurements)		(0.0 ± 0.2) [ab]	(4.7 ± 8.2) [abc]	(5.3 ± 10.2) [c]
	7v7	0.0 ± 0.0 [A]	19.6 ± 22.5 [C]	8.7 ± 12.1 [ABC]
		(0.0 ± 0.0) [a]	(6.6 ± 11.0) [c]	(2.8 ± 7.0) [abc]
Shapiro-Wilk Test: W = 0.89; *p* = <0.001. Levene's Test: F = 2.08; *p* = 0.002				
(Shapiro-Wilk Test: W = 0.75; *p* = <0.001. Levene's Test: F = 1.50; *p* = 0.002)				
V_{Z5} (m)	3v3	0.2 ± 0.7 [A]	0.5 ± 1.8 [A]	0.1 ± 0.4 [A]
30 / 305 SSGs had missing measurements		(0.1 ± 0.3) [a]	(0.2 ± 1.0) [a]	(0.0 ± 0.2) [a]
(101 / 1004 Bouts had missing	5v5	0.0 ± 0.0 [A]	0.0 ± 0.0 [A]	0.2 ± 0.5 [A]
measurements)		(0.0 ± 0.0) [a]	(0.0 ± 0.0) [a]	(0.1 ± 0.3) [a]
	7v7	0.0 ± 0.0 [A]	0.8 ± 1.9 [A]	0.2 ± 0.5 [A]
		(0.0 ± 0.0) [a]	(0.3 ± 1.1) [a]	(0.1 ± 0.3) [a]
Shapiro-Wilk Test: W = 0.39; *p* = <0.001. Levene's Test: F = 1.84; *p* = 0.007				
(Shapiro-Wilk Test: W = 0.21; *p* = <0.001. Levene's Test: F = 1.69; *p* = <0.001)				

<20% (z1), 20-50% (z2), 51-80% (z3), 81-95% (z4), 96-100% (z5) V_{TOP}; *Same grouping letter = not significantly different (H_0 not rejected at $p \leq 0.05$)*

Appendix 12: Youth SSG relative heart rate zones (imputed values - R)

Table I: 5 relative heart rate zones

Youth		Small	Medium	Large
HR_{Z1} (min)	3v3	0.5 ± 1.5 [A]	0.2 ± 0.4 [A]	0.3 ± 0.6 [A]
52 / 305 SSGs had missing measurements		(0.1 ± 0.5) [ab]	(0.0 ± 0.1) [a]	(0.1 ± 0.2) [ab]
(166 / 1004 Bouts had missing	5v5	1.3 ± 2.6 [A]	0.3 ± 0.5 [A]	1.8 ± 4.1 [A]
measurements)		(0.2 ± 0.5) [ab]	(0.1 ± 0.2) [ab]	(0.3 ± 0.8) [b]
	7v7	1.0 ± 1.8 [A]	1.4 ± 2.6 [A]	0.9 ± 1.7 [A]
		(0.2 ± 0.4) [ab]	(0.2 ± 0.6) [ab]	(0.1 ± 0.4) [ab]
Shapiro-Wilk Test: W = 0.59; *p* = <0.001. Levene's Test: F = 2.13; *p* = 0.034				
(Shapiro-Wilk Test: W = 0.45; *p* = <0.001. Levene's Test: F = 1.64; *p* = 0.023)				
HR_{Z2} (min)	3v3	2.2 ± 1.7 [AB]	2.3 ± 1.3 [AB]	1.8 ± 1.6 [B]
52 / 305 SSGs had missing measurements		(0.3 ± 0.4) [a]	(0.3 ± 0.5) [a]	(0.2 ± 0.3) [a]
(166 / 1004 Bouts had missing	5v5	3.7 ± 2.5 [ABC]	3.5 ± 2.6 [ABC]	2.8 ± 2.4 [ABC]
measurements)		(0.5 ± 0.7) [abc]	(0.3 ± 0.4) [ab]	(0.3 ± 0.5) [a]
	7v7	4.0 ± 3.0 [AC]	4.2 ± 2.1 [C]	2.6 ± 2.6 [AB]
		(0.7 ± 0.8) [bc]	(0.7 ± 0.8) [c]	(0.5 ± 0.7) [abc]
Shapiro-Wilk Test: W = 0.96; *p* = <0.001. Levene's Test: F = 2.58; *p* = 0.010				
(Shapiro-Wilk Test: W = 0.81; *p* = <0.001. Levene's Test: F = 2.60; *p* = <0.001)				
HR_{Z3} (min)	3v3	4.6 ± 2.4 [AB]	4.3 ± 1.3 [B]	4.8 ± 1.7 [AB]
52 / 305 SSGs had missing measurements		(0.8 ± 0.8) [ab]	(0.7 ± 0.6) [a]	(0.7 ± 0.6) [a]
(166 / 1004 Bouts had missing	5v5	5.3 ± 2.2 [AB]	6.1 ± 1.6 [AB]	5.2 ± 2.1 [AB]
measurements)		(1.2 ± 1.0) [c]	(1.2 ± 0.8) [abc]	(1.0 ± 0.8) [abc]
	7v7	6.2 ± 2.3 [A]	5.4 ± 2.5 [AB]	5.2 ± 2.2 [AB]
		(1.2 ± 0.9) [c]	(1.1 ± 0.9) [c]	(1.1 ± 0.9) [bc]
Shapiro-Wilk Test: W = 0.97; *p* = <0.001. Levene's Test: F = 1.20; *p* = 0.302				
(Shapiro-Wilk Test: W = 0.93; *p* = <0.001. Levene's Test: F = 2.50; *p* = <0.001)				
HR_{Z4} (min)	3v3	6.4 ± 2.6 [A]	7.2 ± 2.2 [A]	7.1 ± 2.3 [A]
52 / 305 SSGs had missing measurements		(1.7 ± 1.0) [ab]	(1.9 ± 0.9) [a]	(1.9 ± 1.0) [a]
(166 / 1004 Bouts had missing	5v5	5.6 ± 3.2 [A]	6.4 ± 2.3 [A]	6.7 ± 3.1 [A]
measurements)		(1.6 ± 1.1) [ab]	(1.9 ± 0.8) [ab]	(1.7 ± 0.9) [ab]
	7v7	5.5 ± 3.5 [A]	5.5 ± 2.8 [A]	6.1 ± 2.7 [A]
		(1.4 ± 1.1) [ab]	(1.4 ± 1.0) [b]	(1.5 ± 1.0) [ab]
Shapiro-Wilk Test: W = 0.99; *p* = 0.010. Levene's Test: F = 1.40; *p* = 0.199				
(Shapiro-Wilk Test: W = 0.98; *p* = <0.001. Levene's Test: F = 1.26; *p* = 0.173)				
HR_{Z5} (min)	3v3	4.3 ± 3.8 [A]	3.9 ± 2.7 [AB]	3.7 ± 3.1 [AB]
52 / 305 SSGs had missing measurements		(1.1 ± 1.2) [a]	(1.0 ± 0.9) [ac]	(1.1 ± 1.1) [ac]
(166 / 1004 Bouts had missing	5v5	2.2 ± 2.7 [AB]	2.2 ± 2.4 [AB]	2.3 ± 2.5 [AB]
measurements)		(0.6 ± 0.9) [bc]	(0.7 ± 0.8) [abc]	(0.8 ± 0.9) [abc]
	7v7	1.7 ± 2.0 [B]	2.1 ± 2.6 [B]	3.3 ± 3.2 [AB]
		(0.5 ± 0.8) [b]	(0.6 ± 0.9) [b]	(0.8 ± 1.1) [abc]
Shapiro-Wilk Test: W = 0.94; *p* = <0.001. Levene's Test: F = 2.11; *p* = 0.036				
(Shapiro-Wilk Test: W = 0.91; *p* = <0.001. Levene's Test: F = 2.20; *p* = <0.001)				

≤59% (z1), 60–69% (z2), 70–79% (z3), 80–89% (z4), and ≥90% (z5) HR_{MAX}; *Same grouping letter = not significantly different (H_0 not rejected at $p \leq 0.05$)*

U14		Small	Medium	Large
HR_{Z1} (min)	3v3	0.4 ± 0.3 ^{AB}	0.4 ± 0.8 ^{A}	0.3 ± 0.5 ^{AB}
52 / 305 SSGs had missing measurements		(0.3 ± 0.8) ^{ab}	(0.1 ± 0.2) ^{a}	(0.1 ± 0.3) ^{a}
(166 / 1004 Bouts had missing measurements)	5v5	—	0.4 ± 0.5 ^{AB}	—
		(0.1 ± 0.2) ^{a}	(0.1 ± 0.2) ^{a}	(—)
	7v7	—	3.7 ± 4.7 ^{B}	—
		(—)	(0.6 ± 1.1) ^{b}	(0.0 ± 0.1) ^{a}
Shapiro-Wilk Test: W = 0.64; *p* = <0.001. Levene's Test: F = 1.31; *p* = 0.144				
(Shapiro-Wilk Test: W = 0.53; *p* = <0.001. Levene's Test: F = 1.56; *p* = 0.001)				
HR_{Z2} (min)	3v3	2.9 ± 1.4 ^{AB}	2.4 ± 1.7 ^{A}	2.2 ± 2.3 ^{A}
52 / 305 SSGs had missing measurements		(0.3 ± 0.6) ^{a}	(0.5 ± 0.8) ^{ab}	(0.3 ± 0.5) ^{a}
(166 / 1004 Bouts had missing measurements)	5v5	—	4.3 ± 2.3 ^{AB}	—
		(0.4 ± 0.7) ^{ab}	(0.4 ± 0.3) ^{ab}	(—)
	7v7	—	6.0 ± 2.6 ^{B}	—
		(—)	(1.2 ± 0.9) ^{c}	(0.8 ± 0.9) ^{bc}
Shapiro-Wilk Test: W = 0.97; *p* = <0.001. Levene's Test: F = 1.52; *p* = 0.050				
(Shapiro-Wilk Test: W = 0.85; *p* = <0.001. Levene's Test: F = 1.62; *p* = <0.001)				
HR_{Z3} (min)	3v3	3.5 ± 0.9 ^{A}	4.0 ± 1.5 ^{A}	5.9 ± 0.5 ^{A}
52 / 305 SSGs had missing measurements		(0.5 ± 0.4) ^{a}	(0.9 ± 0.7) ^{ab}	(0.9 ± 0.7) ^{ab}
(166 / 1004 Bouts had missing measurements)	5v5	—	6.1 ± 1.5 ^{A}	—
		(1.5 ± 1.2) ^{bc}	(1.3 ± 0.8) ^{bc}	(—)
	7v7	—	6.1 ± 2.9 ^{A}	—
		(—)	(1.5 ± 1.0) ^{bc}	(1.7 ± 0.9) ^{c}
Shapiro-Wilk Test: W = 0.95; *p* = <0.001. Levene's Test: F = 0.68; *p* = 0.896				
(Shapiro-Wilk Test: W = 0.94; *p* = <0.001. Levene's Test: F = 1.10; *p* = 0.260)				
HR_{Z4} (min)	3v3	6.4 ± 2.7 ^{AB}	6.6 ± 3.0 ^{AB}	7.2 ± 0.8 ^{B}
52 / 305 SSGs had missing measurements		(1.9 ± 1.1) ^{a}	(1.6 ± 1.1) ^{a}	(2.0 ± 1.1) ^{a}
(166 / 1004 Bouts had missing measurements)	5v5	—	6.1 ± 1.8 ^{AB}	—
		(1.6 ± 1.2) ^{a}	(1.8 ± 0.6) ^{a}	(—)
	7v7	—	2.5 ± 1.6 ^{A}	—
		(—)	(0.6 ± 0.7) ^{b}	(1.2 ± 1.1) ^{ab}
Shapiro-Wilk Test: W = 0.99; *p* = 0.031. Levene's Test: F = 1.79; *p* = 0.010				
(Shapiro-Wilk Test: W = 0.99; *p* = <0.001. Levene's Test: F = 1.16; *p* = 0.155)				
HR_{Z5} (min)	3v3	4.8 ± 3.2 ^{A}	4.1 ± 3.1 ^{A}	2.3 ± 2.6 ^{A}
52 / 305 SSGs had missing measurements		(1.0 ± 1.0) ^{a}	(0.8 ± 0.8) ^{a}	(0.6 ± 0.9) ^{ab}
(166 / 1004 Bouts had missing measurements)	5v5	—	2.3 ± 2.6 ^{A}	—
		(0.4 ± 0.6) ^{ab}	(0.7 ± 0.8) ^{ab}	(—)
	7v7	—	0.1 ± 0.3 ^{A}	—
		(—)	(0.0 ± 0.2) ^{b}	(0.3 ± 0.7) ^{ab}
Shapiro-Wilk Test: W = 0.96; *p* = <0.001. Levene's Test: F = 1.41; *p* = 0.087				
(Shapiro-Wilk Test: W = 0.95; *p* = <0.001. Levene's Test: F = 1.66; *p* = <0.001)				

≤59% (z1), 60–69% (z2), 70–79% (z3), 80–89% (z4), and ≥90% (z5) HR_{MAX}; *Same grouping letter = not significantly different (H_0 not rejected at $p \leq 0.05$)*

U15		Small	Medium	Large
HR$_{Z1}$ (min)	3v3	0.1 ± 0.2 [A]	0.2 ± 0.2 [A]	0.4 ± 0.6 [A]
52 / 305 SSGs had missing measurements		(0.0 ± 0.1) [ab]	(0.1 ± 0.2) [ab]	(0.2 ± 0.4) [ab]
(166 / 1004 Bouts had missing	5v5	0.5 ± 1.2 [A]	—	1.4 ± 2.1 [A]
measurements)		(0.0 ± 0.1) [ab]	(—)	(0.2 ± 0.3) [ab]
	7v7	2.2 ± 2.2 [A]	1.4 ± 2.0 [A]	1.0 ± 1.8 [A]
		(0.4 ± 0.6) [a]	(0.1 ± 0.3) [ab]	(0.0 ± 0.1) [b]
Shapiro-Wilk Test: W = 0.64; *p* = <0.001. Levene's Test: F = 1.31; *p* = 0.144				
(Shapiro-Wilk Test: W = 0.53; *p* = <0.001. Levene's Test: F = 1.56; *p* = 0.001)				
HR$_{Z2}$ (min)	3v3	0.2 ± 0.1 [A]	1.7 ± 1.6 [AC]	0.9 ± 0.8 [A]
52 / 305 SSGs had missing measurements		(0.1 ± 0.1) [a]	(0.2 ± 0.4) [ab]	(0.3 ± 0.5) [ab]
(166 / 1004 Bouts had missing	5v5	4.0 ± 2.2 [ABC]	—	2.6 ± 1.5 [AC]
measurements)		(0.6 ± 0.8) [ab]	(—)	(0.3 ± 0.2) [a]
	7v7	6.3 ± 3.0 [B]	4.4 ± 1.9 [BC]	3.0 ± 2.4 [AC]
		(1.4 ± 0.8) [c]	(0.7 ± 0.7) [b]	(0.4 ± 0.6) [ab]
Shapiro-Wilk Test: W = 0.97; *p* = <0.001. Levene's Test: F = 1.52; *p* = 0.050				
(Shapiro-Wilk Test: W = 0.85; *p* = <0.001. Levene's Test: F = 1.62; *p* = <0.001)				
HR$_{Z3}$ (min)	3v3	2.7 ± 2.6 [A]	4.4 ± 1.3 [A]	3.1 ± 2.2 [A]
52 / 305 SSGs had missing measurements		(0.4 ± 0.5) [a]	(0.7 ± 0.8) [ab]	(0.7 ± 0.6) [ab]
(166 / 1004 Bouts had missing	5v5	4.5 ± 1.7 [A]	—	5.0 ± 1.7 [A]
measurements)		(0.9 ± 0.8) [ab]	(—)	(1.0 ± 0.6) [ab]
	7v7	6.5 ± 1.4 [A]	5.4 ± 2.6 [A]	5.1 ± 1.6 [A]
		(1.5 ± 0.7) [b]	(1.1 ± 0.9) [ab]	(1.0 ± 0.8) [ab]
Shapiro-Wilk Test: W = 0.95; *p* = <0.001. Levene's Test: F = 0.68; *p* = 0.896				
(Shapiro-Wilk Test: W = 0.94; *p* = <0.001. Levene's Test: F = 1.10; *p* = 0.260)				
HR$_{Z4}$ (min)	3v3	6.9 ± 2.1 [A]	8.5 ± 2.1 [A]	6.8 ± 3.8 [A]
52 / 305 SSGs had missing measurements		(1.3 ± 0.7) [ab]	(2.0 ± 0.8) [a]	(1.5 ± 0.9) [ab]
(166 / 1004 Bouts had missing	5v5	5.9 ± 2.5 [A]	—	6.4 ± 0.8 [A]
measurements)		(1.6 ± 0.9) [a]	(—)	(1.9 ± 0.6) [a]
	7v7	3.2 ± 3.0 [A]	5.3 ± 2.5 [A]	5.8 ± 2.2 [A]
		(0.7 ± 0.9) [b]	(1.5 ± 1.0) [a]	(1.6 ± 0.9) [a]
Shapiro-Wilk Test: W = 0.99; *p* = 0.031. Levene's Test: F = 1.79; *p* = 0.010				
(Shapiro-Wilk Test: W = 0.99; *p* = <0.001. Levene's Test: F = 1.16; *p* = 0.155)				
HR$_{Z5}$ (min)	3v3	7.8 ± 4.5 [A]	3.3 ± 3.1 [AB]	4.4 ± 3.7 [AB]
52 / 305 SSGs had missing measurements		(2.0 ± 1.1) [a]	(1.0 ± 1.0) [abc]	(1.3 ± 1.2) [ab]
(166 / 1004 Bouts had missing	5v5	3.1 ± 3.1 [AB]	—	2.9 ± 2.8 [AB]
measurements)		(0.9 ± 1.1) [b]	(—)	(0.9 ± 0.9) [b]
	7v7	0.2 ± 0.4 [B]	2.3 ± 2.6 [B]	3.3 ± 3.2 [AB]
		(0.1 ± 0.2) [c]	(0.7 ± 0.9) [bc]	(1.0 ± 1.1) [b]
Shapiro-Wilk Test: W = 0.96; *p* = <0.001. Levene's Test: F = 1.41; *p* = 0.087				
(Shapiro-Wilk Test: W = 0.95; *p* = <0.001. Levene's Test: F = 1.66; *p* = <0.001)				

≤59% (z1), 60–69% (z2), 70–79% (z3), 80–89% (z4), and ≥90% (z5) HR_{MAX}; ; *Same grouping letter = not significantly different (H_0 not rejected at $p \leq 0.05$)*

U16		Small	Medium	Large
HR_{Z1} (min)	3v3	0.1 ± 0.2 [A]	0.1 ± 0.1 [A]	0.1 ± 0.1 [A]
52 / 305 SSGs had missing measurements		(0.0 ± 0.0) [a]	(0.0 ± 0.1) [a]	(0.0 ± 0.1) [a]
(166 / 1004 Bouts had missing	5v5	0.0 ± N/A [A]	0.0 ± N/A [A]	—
measurements)		(0.0 ± 0.0) [a]	(0.0 ± 0.0) [a]	(—)
	7v7	0.1 ± 0.2 [A]	0.4 ± 0.3 [A]	0.0 ± 0.0 [A]
		(0.0 ± 0.1) [a]	(0.0 ± 0.0) [a]	(0.0 ± 0.0) [a]
Shapiro-Wilk Test: W = 0.64; *p* = <0.001. Levene's Test: F = 1.31; *p* = 0.144				
(Shapiro-Wilk Test: W = 0.53; *p* = <0.001. Levene's Test: F = 1.56; *p* = 0.001)				
HR_{Z2} (min)	3v3	4.7 ± 2.0 [A]	2.7 ± 0.7 [A]	1.9 ± 1.6 [A]
52 / 305 SSGs had missing measurements		(0.5 ± 0.3) [a]	(0.3 ± 0.2) [a]	(0.2 ± 0.2) [a]
(166 / 1004 Bouts had missing	5v5	1.2 ± N/A [A]	2.1 ± N/A [A]	—
measurements)		(0.2 ± 0.3) [a]	(0.2 ± 0.2) [a]	(—)
	7v7	3.0 ± 1.8 [A]	4.6 ± 1.9 [A]	1.4 ± 1.0 [A]
		(0.2 ± 0.2) [a]	(0.6 ± 0.8) [a]	(0.2 ± 0.2) [a]
Shapiro-Wilk Test: W = 0.97; *p* = <0.001. Levene's Test: F = 1.52; *p* = 0.050				
(Shapiro-Wilk Test: W = 0.85; *p* = <0.001. Levene's Test: F = 1.62; *p* = <0.001)				
HR_{Z3} (min)	3v3	5.1 ± 1.2 [A]	4.1 ± 1.1 [A]	4.6 ± 1.8 [A]
52 / 305 SSGs had missing measurements		(1.0 ± 0.7) [ab]	(0.5 ± 0.5) [b]	(0.6 ± 0.5) [b]
(166 / 1004 Bouts had missing	5v5	5.2 ± N/A [A]	6.9 ± N/A [A]	—
measurements)		(0.4 ± 0.2) [ab]	(0.5 ± 0.1) [ab]	(—)
	7v7	8.2 ± 0.8 [A]	7.2 ± 0.9 [A]	6.8 ± 3.5 [A]
		(1.6 ± 0.8) [a]	(1.4 ± 0.9) [ab]	(1.2 ± 1.0) [ab]
Shapiro-Wilk Test: W = 0.95; *p* = <0.001. Levene's Test: F = 0.68; *p* = 0.896				
(Shapiro-Wilk Test: W = 0.94; *p* = <0.001. Levene's Test: F = 1.10; *p* = 0.260)				
HR_{Z4} (min)	3v3	6.4 ± 0.6 [A]	6.7 ± 1.9 [A]	6.0 ± 1.7 [A]
52 / 305 SSGs had missing measurements		(1.9 ± 0.6) [a]	(1.8 ± 0.8) [a]	(1.6 ± 0.9) [a]
(166 / 1004 Bouts had missing	5v5	8.0 ± N/A [A]	6.8 ± N/A [A]	—
measurements)		(2.4 ± 0.8) [a]	(2.0 ± 0.8) [a]	(—)
	7v7	5.9 ± 1.9 [A]	6.3 ± 2.4 [A]	6.5 ± 2.3 [A]
		(1.7 ± 0.8) [a]	(1.9 ± 1.3) [a]	(1.7 ± 0.8) [a]
Shapiro-Wilk Test: W = 0.99; *p* = 0.031. Levene's Test: F = 1.79; *p* = 0.010				
(Shapiro-Wilk Test: W = 0.99; *p* = <0.001. Levene's Test: F = 1.16; *p* = 0.155)				
HR_{Z5} (min)	3v3	1.7 ± 2.4 [A]	4.4 ± 2.6 [A]	5.4 ± 2.7 [A]
52 / 305 SSGs had missing measurements		(0.6 ± 0.8) [abc]	(1.3 ± 0.8) [ac]	(1.6 ± 1.1) [c]
(166 / 1004 Bouts had missing	5v5	3.6 ± N/A [A]	4.3 ± N/A [A]	—
measurements)		(0.9 ± 1.1) [abc]	(1.4 ± 0.9) [abc]	(—)
	7v7	1.1 ± 1.1 [A]	0.2 ± 0.2 [A]	3.3 ± 3.7 [A]
		(0.3 ± 0.7) [ab]	(0.1 ± 0.1) [b]	(0.9 ± 1.0) [abc]
Shapiro-Wilk Test: W = 0.96; *p* = <0.001. Levene's Test: F = 1.41; *p* = 0.087				
(Shapiro-Wilk Test: W = 0.95; *p* = <0.001. Levene's Test: F = 1.66; *p* = <0.001)				

≤59% (z1), 60–69% (z2), 70–79% (z3), 80–89% (z4), and ≥90% (z5) HR_{MAX}; ; *Same grouping letter = not significantly different (H_0 not rejected at $p \leq 0.05$)*

U18		Small	Medium	Large
HRz1 (min)	3v3	0.7 ± 1.8 [A]	0.0 ± 0.1 [A]	0.3 ± 0.7 [A]
52 / 305 SSGs had missing measurements		(0.1 ± 0.3) [abc]	(0.0 ± 0.0) [b]	(0.1 ± 0.2) [bc]
(166 / 1004 Bouts had missing	5v5	2.2 ± 3.7 [A]	0.2 ± 0.5 [A]	2.1 ± 5.0 [A]
measurements)		(0.4 ± 0.9) [a]	(0.0 ± 0.1) [abc]	(0.3 ± 1.0) [ac]
	7v7	0.1 ± 0.2 [A]	0.1 ± 0.2 [A]	1.0 ± 1.9 [A]
		(0.0 ± 0.0) [b]	(0.0 ± 0.0) [bc]	(0.2 ± 0.6) [abc]
Shapiro-Wilk Test: W = 0.64; *p* = <0.001. Levene's Test: F = 1.31; *p* = 0.144				
(Shapiro-Wilk Test: W = 0.53; *p* = <0.001. Levene's Test: F = 1.56; *p* = 0.001)				
HRz2 (min)	3v3	2.2 ± 1.5 [A]	2.1 ± 1.3 [A]	1.9 ± 1.5 [A]
52 / 305 SSGs had missing measurements		(0.3 ± 0.3) [a]	(0.2 ± 0.2) [a]	(0.2 ± 0.2) [a]
(166 / 1004 Bouts had missing	5v5	3.6 ± 2.9 [A]	2.8 ± 3.1 [A]	2.9 ± 2.9 [A]
measurements)		(0.6 ± 0.7) [a]	(0.3 ± 0.5) [a]	(0.4 ± 0.6) [a]
	7v7	1.9 ± 1.3 [A]	2.6 ± 1.2 [A]	2.6 ± 3.0 [A]
		(0.1 ± 0.2) [a]	(0.2 ± 0.4) [a]	(0.5 ± 0.7) [a]
Shapiro-Wilk Test: W = 0.97; *p* = <0.001. Levene's Test: F = 1.52; *p* = 0.050				
(Shapiro-Wilk Test: W = 0.85; *p* = <0.001. Levene's Test: F = 1.62; *p* = <0.001)				
HRz3 (min)	3v3	5.1 ± 2.5 [A]	4.6 ± 1.3 [A]	4.9 ± 1.5 [A]
52 / 305 SSGs had missing measurements		(0.9 ± 0.9) [ab]	(0.7 ± 0.6) [b]	(0.7 ± 0.6) [b]
(166 / 1004 Bouts had missing	5v5	6.2 ± 2.6 [A]	5.9 ± 1.9 [A]	5.3 ± 2.4 [A]
measurements)		(1.3 ± 1.1) [a]	(1.0 ± 0.8) [ab]	(1.0 ± 0.8) [ab]
	7v7	5.3 ± 2.9 [A]	4.6 ± 2.2 [A]	4.9 ± 2.4 [A]
		(0.7 ± 0.9) [ab]	(0.7 ± 0.8) [ab]	(0.9 ± 0.9) [ab]
Shapiro-Wilk Test: W = 0.95; *p* = <0.001. Levene's Test: F = 0.68; *p* = 0.896				
(Shapiro-Wilk Test: W = 0.94; *p* = <0.001. Levene's Test: F = 1.10; *p* = 0.260)				
HRz4 (min)	3v3	6.4 ± 2.9 [A]	7.6 ± 1.8 [A]	7.5 ± 2.4 [A]
52 / 305 SSGs had missing measurements		(1.6 ± 1.0) [a]	(2.0 ± 0.8) [a]	(2.0 ± 0.9) [a]
(166 / 1004 Bouts had missing	5v5	4.9 ± 4.1 [A]	6.7 ± 3.3 [A]	6.8 ± 3.9 [A]
measurements)		(1.3 ± 1.2) [a]	(2.0 ± 0.9) [a]	(1.7 ± 1.1) [a]
	7v7	7.6 ± 3.0 [A]	7.8 ± 2.0 [A]	6.3 ± 3.2 [A]
		(2.1 ± 0.9) [a]	(2.0 ± 0.9) [a]	(1.5 ± 1.1) [a]
Shapiro-Wilk Test: W = 0.99; *p* = 0.031. Levene's Test: F = 1.79; *p* = 0.010				
(Shapiro-Wilk Test: W = 0.99; *p* = <0.001. Levene's Test: F = 1.16; *p* = 0.155)				
HRz5 (min)	3v3	3.8 ± 3.7 [A]	3.6 ± 2.7 [A]	3.4 ± 3.1 [A]
52 / 305 SSGs had missing measurements		(1.0 ± 1.2) [a]	(1.0 ± 0.9) [a]	(1.0 ± 1.1) [a]
(166 / 1004 Bouts had missing	5v5	1.1 ± 2.0 [A]	1.7 ± 2.4 [A]	2.0 ± 2.3 [A]
measurements)		(0.3 ± 0.7) [a]	(0.6 ± 0.8) [a]	(0.7 ± 0.9) [a]
	7v7	3.3 ± 2.0 [A]	3.7 ± 2.7 [A]	3.2 ± 3.3 [A]
		(1.1 ± 0.9) [a]	(1.1 ± 1.0) [a]	(0.9 ± 1.1) [a]
Shapiro-Wilk Test: W = 0.96; *p* = <0.001. Levene's Test: F = 1.41; *p* = 0.087				
(Shapiro-Wilk Test: W = 0.95; *p* = <0.001. Levene's Test: F = 1.66; *p* = <0.001)				

≤59% (z1), 60–69% (z2), 70–79% (z3), 80–89% (z4), and ≥90% (z5) HR_{MAX}; *Same grouping letter = not significantly different (H_0 not rejected at $p \leq 0.05$)*

Appendix 13: Youth SSG age cohorts multivariate tests (complete cases - SPSS)

Table I Multivariate test - Age group-specific main & interaction effects of SSG design variables for overall performance

		COMPLETE CASES (SPSS)			
			F	*p*	Pr
P	SSG	No.	5.04	<0.001	1.00
O		Pitch	5.32	<0.001	1.00
O		Age	3.94	<0.001	1.00
L		No.*Pitch	2.21	<0.001	1.00
E		No.*Age	6.71	<0.001	1.00
D		Pitch*Age	1.70	<0.001	1.00
		No.*Pitch*Age	2.12	<0.001	1.00
Y	Bout	No.	5.36	<0.001	1.00
O		Pitch	7.08	<0.001	1.00
U		Age	7.19	<0.001	1.00
T		Bout	3.92	<0.001	1.00
H		No.*Pitch	2.53	<0.001	1.00
		No.*Bout	1.28	0.012	1.00
		No.*Age	5.02	<0.001	1.00
		Pitch*Age	3.10	<0.001	1.00
		Pitch*Bout	1.17	0.078	1.00
		Age*Bout	1.05	0.363	1.00
		No.*Pitch*Age	2.27	<0.001	1.00
		No.*Pitch*Bout	1.33	<0.001	1.00
		No.*Bout*Age	1.31	0.008	1.00
		Pitch*Age*Bout	1.60	<0.001	1.00
		No.*Pitch*Age*Bout	1.60	<0.001	1.00
U14	SSG	No.	2.67	0.311[A#,C#]	0.17
		Pitch	2.29	0.351[A#,B#]	0.16
		No.*Pitch	-	-	-
	Bout	No.	3.52	<0.001	1.00
		Pitch	2.61	<0.001[C±]	1.00
		Bout	2.35	<0.001	1.00
		No.*Pitch	1.86	<0.001	1.00
		No.*Bout	1.45	0.002	1.00
		Pitch*Bout	1.65	<0.001[C#]	1.00
		No.*Pitch*Bout	1.09	0.311	1.00
U15	SSG	No.	3.82	<0.001	1.00
		Pitch	1.82	0.012[C±]	1.00
		No.*Pitch	1.86	0.002 [C±]	1.00
	Bout	No.	3.12	<0.001	1.00
		Pitch	3.38	<0.001	1.00
		Bout	2.47	<0.001	1.00
		No.*Pitch	2.26	<0.001	1.00
		No.*Bout	1.73	<0.001	1.00
		Pitch*Bout	1.58	<0.001[B±]	1.00
		No.*Pitch*Bout	1.61	<0.001	1.00
U16	SSG	No.	4.16	0.367[B#,C#]	0.12
		Pitch	4.07	0.216[B#,C#]	0.23
		No.*Pitch	7.12	0.130[C#]	0.34
	Bout	No.	3.58	0.399[A#,B#,C#]	0.11
		Pitch	1.14	0.579[A#,B#,c#]	0.10
		Bout	1.23	0.554[A#,C#]	0.10
		No.*Pitch	0.79	0.712[A#]	0.09

		No.*Bout	<u>0.78</u>	<u>0.717[C#]</u>	<u>0.09</u>
		Pitch*Bout	<u>0.95</u>	<u>0.606[a#]</u>	<u>0.23</u>
		No.*Pitch*Bout	<u>0.70</u>	<u>0.796</u>	<u>0.17</u>
U18	SSG	No.	8.15	<0.001	1.00
		Pitch	2.44	0.001	1.00
		No.*Pitch	2.43	0.001[β]	1.00
	Bout	No.	6.43	<0.001	1.00
		Pitch	3.91	<0.001	1.00
		Bout	2.56	<0.001[b]	1.00
		No.*Pitch	1.59	0.003[c]	1.00
		No.*Bout	1.24	0.038	1.00
		Pitch*Bout	<u>1.02</u>	<u>0.431</u>	<u>1.00</u>
		No.*Pitch*Bout	<u>1.12</u>	<u>0.188[α]</u>	<u>1.00</u>

Pooled= (U14+U15), (U16+U18); SSG= full small-sided game; Bout = SSG bout (1, 2, 3); No.= Player No. (3v3, 5v5, 7v7); Pitch= Pitch size (S, M, L); Age= Age category (U14, U15, U16, U18); A/a/α= Reversed significance for core outcome measures ($p \leq 0.01/\leq 0.05/=0.07$); B/b/β= Reversed significance for TD in V_Z ($p \leq 0.01/\leq 0.08/=0.08$); C/c= Reversed significance for time in HR_Z ($p \leq 0.01/\leq 0.05$); # = At sufficient statistical power (Pr>0.80); ±= At near sufficient statistical power (Pr>0.70)

Appendix 14: Youth SSG formats bout differences – General performance measures (imputed values R)

Table I: General performance measures

Statistically significantly different ($p \leq 0.05$)
Trend to significancy ($p = 0.05\text{-}0.1$)

YOUTH	Pitch * No.	Comparison	Estimate	95% Adj. C.I.	Adj. *p*-value
TD (m)	S : 3v3	Bout1 − Bout2	13.42	(-25.81,52.64)	0.701
48 / 1004 Bouts with missing measurements.		Bout1 − Bout3	37.47	(-0.83,75.77)	0.057
		Bout2 − Bout3	24.05	(-15.17,63.27)	0.321
	S : 5v5	Bout1 − Bout2	−24.79	(-73.34,23.77)	0.454
		Bout1 − Bout3	−33.85	(-88.74,21.03)	0.317
		Bout2 − Bout3	−9.07	(-63.95,45.82)	0.920
	S : 7v7	Bout1 − Bout2	12.15	(-37.30,61.59)	0.833
		Bout1 − Bout3	14.66	(-35.25,64.58)	0.770
		Bout2 − Bout3	2.52	(-47.40,52.43)	0.992
	M : 3v3	Bout1 − Bout2	−0.46	(-38.34,37.42)	1.000
		Bout1 − Bout3	22.56	(-16.72,61.84)	0.369
		Bout2 − Bout3	23.02	(-16.26,62.29)	0.354
	M : 5v5	Bout1 − Bout2	−10.00	(-72.31,52.31)	0.925
		Bout1 − Bout3	6.00	(-56.31,68.31)	0.972
		Bout2 − Bout3	16.00	(-46.31,78.31)	0.819
	M : 7v7	Bout1 − Bout2	2.21	(-34.31,38.73)	0.989
		Bout1 − Bout3	−7.59	(-44.30,29.11)	0.878
		Bout2 − Bout3	−9.80	(-46.32,26.72)	0.804
	L : 3v3	Bout1 − Bout2	27.53	(-14.15,69.20)	0.268
		Bout1 − Bout3	−10.71	(-52.67,31.25)	0.821
		Bout2 − Bout3	−38.24	(-80.20,3.72)	0.083
	L : 5v5	Bout1 − Bout2	22.00	(-25.71,69.71)	0.525
		Bout1 − Bout3	38.55	(-9.16,86.26)	0.140
		Bout2 − Bout3	16.55	(-31.16,64.26)	0.694
	L : 7v7	Bout1 − Bout2	17.72	(-18.08,53.52)	0.476
		Bout1 − Bout3	4.59	(-34.48,43.67)	0.959
		Bout2 − Bout3	−13.13	(-52.36,26.11)	0.712
RD ($m \cdot min^{-1}$)	S : 3v3	Bout1 − Bout2	2.12	(-5.49,9.72)	0.791
47 / 1004 Bouts with missing measurements.		Bout1 − Bout3	7.98	(0.55,15.40)	0.032
		Bout2 − Bout3	5.86	(-1.74,13.46)	0.167
	S : 5v5	Bout1 − Bout2	−4.07	(-13.48,5.34)	0.567
		Bout1 − Bout3	−8.35	(-18.99,2.28)	0.156
		Bout2 − Bout3	−4.28	(-14.92,6.36)	0.612
	S : 7v7	Bout1 − Bout2	0.48	(-9.10,10.06)	0.992
		Bout1 − Bout3	−0.62	(-10.29,9.06)	0.988
		Bout2 − Bout3	−1.10	(-10.77,8.58)	0.962
	M : 3v3	Bout1 − Bout2	0.35	(-6.99,7.69)	0.993
		Bout1 − Bout3	4.84	(-2.77,12.45)	0.295

YOUTH	Pitch * No.	Comparison	Estimate	95% Adj. C.I.	Adj. *p*-value
		Bout2 − Bout3	4.49	(-3.12,12.11)	0.349
	M : 5v5	Bout1 − Bout2	1.71	(-10.37,13.78)	0.941
		Bout1 − Bout3	3.76	(-8.31,15.84)	0.745
		Bout2 − Bout3	2.06	(-10.02,14.14)	0.916
	M : 7v7	Bout1 − Bout2	1.28	(-5.80,8.36)	0.905
		Bout1 − Bout3	−1.35	(-8.46,5.77)	0.897
		Bout2 − Bout3	−2.63	(-9.71,4.45)	0.658
	L : 3v3	Bout1 − Bout2	8.42	(0.34,16.50)	0.039
		Bout1 − Bout3	10.27	(2.14,18.40)	0.009
		Bout2 − Bout3	1.85	(-6.29,9.98)	0.855
	L : 5v5	Bout1 − Bout2	4.14	(-5.11,13.38)	0.545
		Bout1 − Bout3	8.00	(-1.25,17.25)	0.105
		Bout2 − Bout3	3.86	(-5.38,13.11)	0.589
	L : 7v7	Bout1 − Bout2	5.08	(-1.83,11.98)	0.196
		Bout1 − Bout3	0.93	(-6.64,8.50)	0.955
		Bout2 − Bout3	−4.15	(-11.72,3.43)	0.404
V_{AVG} (km·h^{-1})	S : 3v3	Bout1 − Bout2	0.12	(-0.34,0.57)	0.819
47 / 1004 Bouts with missing measurements.		Bout1 − Bout3	0.47	(0.02,0.92)	0.036
		Bout2 − Bout3	0.35	(-0.10,0.81)	0.164
	S : 5v5	Bout1 − Bout2	−0.25	(-0.81,0.32)	0.563
		Bout1 − Bout3	−0.51	(-1.15,0.13)	0.150
		Bout2 − Bout3	−0.26	(-0.90,0.38)	0.604
	S : 7v7	Bout1 − Bout2	0.03	(-0.55,0.60)	0.994
		Bout1 − Bout3	−0.05	(-0.63,0.53)	0.980
		Bout2 − Bout3	−0.07	(-0.65,0.51)	0.953
	M : 3v3	Bout1 − Bout2	0.02	(-0.42,0.47)	0.991
		Bout1 − Bout3	0.29	(-0.17,0.75)	0.303
		Bout2 − Bout3	0.26	(-0.19,0.72)	0.366
	M : 5v5	Bout1 − Bout2	0.10	(-0.63,0.83)	0.944
		Bout1 − Bout3	0.24	(-0.49,0.96)	0.727
		Bout2 − Bout3	0.14	(-0.59,0.86)	0.900
	M : 7v7	Bout1 − Bout2	0.07	(-0.35,0.50)	0.920
		Bout1 − Bout3	−0.08	(-0.50,0.35)	0.910
		Bout2 − Bout3	−0.15	(-0.57,0.28)	0.700
	L : 3v3	Bout1 − Bout2	0.51	(0.02,0.99)	0.039
		Bout1 − Bout3	0.62	(0.13,1.11)	0.009
		Bout2 − Bout3	0.11	(-0.38,0.60)	0.855
	L : 5v5	Bout1 − Bout2	0.24	(-0.31,0.80)	0.565
		Bout1 − Bout3	0.47	(-0.08,1.03)	0.114
		Bout2 − Bout3	0.23	(-0.32,0.79)	0.592
	L : 7v7	Bout1 − Bout2	0.30	(-0.11,0.72)	0.199
		Bout1 − Bout3	0.04	(-0.41,0.50)	0.972
		Bout2 − Bout3	−0.26	(-0.71,0.20)	0.374
V_{MAX} (km·h^{-1})	S : 3v3	Bout1 − Bout2	−0.58	(-2.40,1.24)	0.734

YOUTH	Pitch * No.	Comparison	Estimate	95% Adj. C.I.	Adj. *p*-value
47 / 1004 Bouts with missing measurements.		Bout1 − Bout3	−0.05	(-1.83,1.72)	0.997
		Bout2 − Bout3	0.53	(-1.29,2.35)	0.773
	S : 5v5	Bout1 − Bout2	−1.18	(-3.43,1.07)	0.436
		Bout1 − Bout3	−1.12	(-3.66,1.42)	0.556
		Bout2 − Bout3	0.06	(-2.49,2.60)	0.998
	S : 7v7	Bout1 − Bout2	1.00	(-1.29,3.30)	0.559
		Bout1 − Bout3	0.63	(-1.68,2.94)	0.798
		Bout2 − Bout3	−0.37	(-2.69,1.94)	0.924
	M : 3v3	Bout1 − Bout2	−0.90	(-2.66,0.86)	0.452
		Bout1 − Bout3	−0.21	(-2.03,1.61)	0.962
		Bout2 − Bout3	0.69	(-1.13,2.51)	0.644
	M : 5v5	Bout1 − Bout2	−0.42	(-3.31,2.47)	0.938
		Bout1 − Bout3	0.04	(-2.85,2.92)	1.000
		Bout2 − Bout3	0.45	(-2.44,3.34)	0.928
	M : 7v7	Bout1 − Bout2	−0.34	(-2.04,1.35)	0.883
		Bout1 − Bout3	−0.72	(-2.42,0.98)	0.581
		Bout2 − Bout3	−0.38	(-2.07,1.32)	0.860
	L : 3v3	Bout1 − Bout2	0.34	(-1.60,2.27)	0.912
		Bout1 − Bout3	0.19	(-1.75,2.14)	0.970
		Bout2 − Bout3	−0.14	(-2.09,1.80)	0.984
	L : 5v5	Bout1 − Bout2	0.44	(-1.77,2.65)	0.888
		Bout1 − Bout3	−0.78	(-2.99,1.44)	0.688
		Bout2 − Bout3	−1.21	(-3.43,1.00)	0.402
	L : 7v7	Bout1 − Bout2	0.53	(-1.12,2.18)	0.729
		Bout1 − Bout3	0.70	(-1.11,2.52)	0.632
		Bout2 − Bout3	0.17	(-1.64,1.98)	0.973
HR_{AVG} (% HR_{MAX})	S : 3v3	Bout1 − Bout2	−3.51	(-7.40,0.38)	0.087
151 / 1004 Bouts with missing measurements.		Bout1 − Bout3	−1.45	(-5.23,2.34)	0.642
		Bout2 − Bout3	2.06	(-1.83,5.95)	0.427
	S : 5v5	Bout1 − Bout2	−1.29	(-5.99,3.41)	0.796
		Bout1 − Bout3	−2.65	(-7.89,2.58)	0.460
		Bout2 − Bout3	−1.36	(-6.52,3.79)	0.809
	S : 7v7	Bout1 − Bout2	−2.79	(-7.79,2.20)	0.389
		Bout1 − Bout3	−3.47	(-8.52,1.58)	0.240
		Bout2 − Bout3	−0.68	(-5.73,4.37)	0.946
	M : 3v3	Bout1 − Bout2	−2.05	(-5.87,1.76)	0.415
		Bout1 − Bout3	−1.83	(-5.77,2.12)	0.522
		Bout2 − Bout3	0.23	(-3.69,4.15)	0.990
	M : 5v5	Bout1 − Bout2	−1.62	(-8.02,4.78)	0.823
		Bout1 − Bout3	0.10	(-6.19,6.40)	0.999
		Bout2 − Bout3	1.72	(-4.57,8.02)	0.796
	M : 7v7	Bout1 − Bout2	−1.58	(-5.17,2.01)	0.556
		Bout1 − Bout3	−2.59	(-6.20,1.02)	0.212
		Bout2 − Bout3	−1.01	(-4.60,2.58)	0.787

YOUTH	Pitch * No.	Comparison	Estimate	95% Adj. C.I.	Adj. *p*-value
	L : 3v3	Bout1 − Bout2	−2.91	(-7.01,1.20)	0.221
		Bout1 − Bout3	−1.96	(-6.07,2.15)	0.501
		Bout2 − Bout3	0.94	(-3.16,5.05)	0.852
	L : 5v5	Bout1 − Bout2	−4.33	(-9.08,0.42)	0.082
		Bout1 − Bout3	−4.13	(-8.88,0.62)	0.103
		Bout2 − Bout3	0.20	(-4.41,4.81)	0.994
	L : 7v7	Bout1 − Bout2	−3.82	(-7.32,-0.32)	0.028
		Bout1 − Bout3	−4.30	(-8.11,-0.48)	0.023
		Bout2 − Bout3	−0.47	(-4.22,3.27)	0.952
HRMAX (%HRMAX)	S : 3v3	Bout1 − Bout2	−3.06	(-6.66,0.54)	0.114
151 / 1004 Bouts with		Bout1 − Bout3	−1.20	(-4.70,2.30)	0.701
missing measurements.		Bout2 − Bout3	1.86	(-1.74,5.46)	0.447
	S : 5v5	Bout1 − Bout2	0.17	(-4.18,4.52)	0.995
		Bout1 − Bout3	−1.23	(-6.08,3.61)	0.821
		Bout2 − Bout3	−1.41	(-6.18,3.36)	0.768
	S : 7v7	Bout1 − Bout2	−2.17	(-6.80,2.45)	0.512
		Bout1 − Bout3	−1.17	(-5.84,3.51)	0.827
		Bout2 − Bout3	1.00	(-3.67,5.68)	0.869
	M : 3v3	Bout1 − Bout2	−1.47	(-4.99,2.06)	0.592
		Bout1 − Bout3	−1.76	(-5.41,1.89)	0.493
		Bout2 − Bout3	−0.30	(-3.93,3.33)	0.980
	M : 5v5	Bout1 − Bout2	−0.72	(-6.65,5.20)	0.956
		Bout1 − Bout3	0.03	(-5.79,5.86)	1.000
		Bout2 − Bout3	0.75	(-5.07,6.58)	0.950
	M : 7v7	Bout1 − Bout2	−0.83	(-4.15,2.50)	0.829
		Bout1 − Bout3	−2.42	(-5.76,0.92)	0.206
		Bout2 − Bout3	−1.59	(-4.92,1.73)	0.498
	L : 3v3	Bout1 − Bout2	−0.91	(-4.71,2.89)	0.840
		Bout1 − Bout3	−0.35	(-4.15,3.45)	0.974
		Bout2 − Bout3	0.56	(-3.24,4.36)	0.936
	L : 5v5	Bout1 − Bout2	−2.60	(-7.00,1.80)	0.348
		Bout1 − Bout3	−3.69	(-8.09,0.71)	0.120
		Bout2 − Bout3	−1.09	(-5.36,3.17)	0.819
	L : 7v7	Bout1 − Bout2	−2.23	(-5.47,1.01)	0.239
		Bout1 − Bout3	−2.96	(-6.49,0.57)	0.121
		Bout2 − Bout3	−0.73	(-4.20,2.74)	0.875
RPE (6-20)	S : 3v3	Bout1 − Bout2	−1.80	(-2.88,-0.73)	<0.001
2 / 1004 Bouts with		Bout1 − Bout3	−1.53	(-2.58,-0.48)	0.002
missing measurements.		Bout2 − Bout3	0.27	(-0.80,1.35)	0.825
	S : 5v5	Bout1 − Bout2	−1.63	(-2.95,-0.32)	0.010
		Bout1 − Bout3	−2.23	(-3.71,-0.76)	0.001
		Bout2 − Bout3	−0.60	(-2.07,0.87)	0.604
	S : 7v7	Bout1 − Bout2	−0.74	(-2.13,0.65)	0.422
		Bout1 − Bout3	−1.89	(-3.28,-0.50)	0.004

YOUTH	Pitch * No.	Comparison	Estimate	95% Adj. C.I.	Adj. *p*-value
		Bout2 − Bout3	−1.15	(-2.54,0.24)	0.127
	M : 3v3	Bout1 − Bout2	−1.13	(-2.19,-0.07)	0.034
		Bout1 − Bout3	−2.07	(-3.17,-0.96)	<0.001
		Bout2 − Bout3	−0.94	(-2.04,0.17)	0.114
	M : 5v5	Bout1 − Bout2	−1.30	(-2.91,0.31)	0.141
		Bout1 − Bout3	−3.35	(-4.96,-1.74)	<0.001
		Bout2 − Bout3	−2.05	(-3.66,-0.44)	0.008
	M : 7v7	Bout1 − Bout2	−0.73	(-1.70,0.24)	0.181
		Bout1 − Bout3	−1.82	(-2.79,-0.84)	<0.001
		Bout2 − Bout3	−1.09	(-2.06,-0.12)	0.024
	L : 3v3	Bout1 − Bout2	−1.47	(-2.62,-0.33)	0.007
		Bout1 − Bout3	−1.91	(-3.06,-0.76)	<0.001
		Bout2 − Bout3	−0.44	(-1.58,0.71)	0.646
	L : 5v5	Bout1 − Bout2	−1.31	(-2.65,0.03)	0.057
		Bout1 − Bout3	−2.41	(-3.75,-1.07)	<0.001
		Bout2 − Bout3	−1.10	(-2.44,0.24)	0.130
	L : 7v7	Bout1 − Bout2	−1.27	(-2.27,-0.27)	0.008
		Bout1 − Bout3	−1.25	(-2.35,-0.16)	0.020
		Bout2 − Bout3	0.02	(-1.08,1.11)	0.999
Sprint·min^{-1}	S : 3v3	Bout1 − Bout2	0.04	(-0.56,0.64)	0.988
47 / 1004 Bouts with missing measurements.		Bout1 − Bout3	0.38	(-0.20,0.97)	0.277
		Bout2 − Bout3	0.35	(-0.26,0.95)	0.369
	S : 5v5	Bout1 − Bout2	−0.09	(-0.83,0.66)	0.957
		Bout1 − Bout3	−0.48	(-1.32,0.36)	0.376
		Bout2 − Bout3	−0.39	(-1.23,0.45)	0.523
	S : 7v7	Bout1 − Bout2	−0.11	(-0.87,0.65)	0.937
		Bout1 − Bout3	−0.22	(-0.98,0.55)	0.782
		Bout2 − Bout3	−0.11	(-0.87,0.66)	0.943
	M : 3v3	Bout1 − Bout2	0.07	(-0.51,0.65)	0.956
		Bout1 − Bout3	0.05	(-0.55,0.65)	0.978
		Bout2 − Bout3	−0.02	(-0.62,0.58)	0.997
	M : 5v5	Bout1 − Bout2	0.37	(-0.59,1.32)	0.639
		Bout1 − Bout3	0.12	(-0.84,1.07)	0.955
		Bout2 − Bout3	−0.25	(-1.21,0.71)	0.813
	M : 7v7	Bout1 − Bout2	0.22	(-0.34,0.78)	0.624
		Bout1 − Bout3	0.22	(-0.34,0.78)	0.632
		Bout2 − Bout3	−0.00	(-0.56,0.56)	1.000
	L : 3v3	Bout1 − Bout2	0.25	(-0.39,0.89)	0.630
		Bout1 − Bout3	0.46	(-0.18,1.11)	0.212
		Bout2 − Bout3	0.21	(-0.43,0.86)	0.720
	L : 5v5	Bout1 − Bout2	0.15	(-0.59,0.88)	0.886
		Bout1 − Bout3	0.62	(-0.11,1.35)	0.115
		Bout2 − Bout3	0.47	(-0.26,1.21)	0.282
	L : 7v7	Bout1 − Bout2	0.23	(-0.32,0.78)	0.583

YOUTH	Pitch * No.	Comparison	Estimate	95% Adj. C.I.	Adj. *p*-value
		Bout1 − Bout3	0.11	(-0.49,0.71)	0.896
		Bout2 − Bout3	−0.12	(-0.72,0.48)	0.891
HIacc	S : 3v3	Bout1 − Bout2	0.21	(-2.03,2.45)	0.973
47 / 1004 Bouts with missing measurements.		Bout1 − Bout3	2.38	(0.19,4.57)	0.029
		Bout2 − Bout3	2.16	(-0.08,4.41)	0.061
	S : 5v5	Bout1 − Bout2	0.46	(-2.31,3.24)	0.918
		Bout1 − Bout3	−2.12	(-5.26,1.01)	0.251
		Bout2 − Bout3	−2.59	(-5.72,0.55)	0.129
	S : 7v7	Bout1 − Bout2	−0.41	(-3.23,2.42)	0.939
		Bout1 − Bout3	0.56	(-2.29,3.41)	0.890
		Bout2 − Bout3	0.97	(-1.89,3.82)	0.706
	M : 3v3	Bout1 − Bout2	1.52	(-0.64,3.69)	0.225
		Bout1 − Bout3	1.07	(-1.18,3.31)	0.505
		Bout2 − Bout3	−0.46	(-2.70,1.79)	0.882
	M : 5v5	Bout1 − Bout2	0.59	(-2.97,4.15)	0.920
		Bout1 − Bout3	1.94	(-1.62,5.50)	0.407
		Bout2 − Bout3	1.35	(-2.21,4.91)	0.645
	M : 7v7	Bout1 − Bout2	0.18	(-1.90,2.27)	0.977
		Bout1 − Bout3	1.16	(-0.93,3.26)	0.394
		Bout2 − Bout3	0.98	(-1.10,3.07)	0.511
	L : 3v3	Bout1 − Bout2	1.50	(-0.88,3.88)	0.301
		Bout1 − Bout3	2.01	(-0.39,4.40)	0.121
		Bout2 − Bout3	0.51	(-1.89,2.90)	0.873
	L : 5v5	Bout1 − Bout2	0.55	(-2.17,3.28)	0.883
		Bout1 − Bout3	2.07	(-0.66,4.79)	0.176
		Bout2 − Bout3	1.52	(-1.21,4.24)	0.392
	L : 7v7	Bout1 − Bout2	1.77	(-0.27,3.80)	0.103
		Bout1 − Bout3	1.02	(-1.21,3.25)	0.533
		Bout2 − Bout3	−0.75	(-2.98,1.48)	0.709
HIdec	S : 3v3	Bout1 − Bout2	−0.02	(-1.07,1.04)	0.999
47 / 1004 Bouts with missing measurements.		Bout1 − Bout3	0.27	(-0.76,1.30)	0.816
		Bout2 − Bout3	0.28	(-0.77,1.34)	0.802
	S : 5v5	Bout1 − Bout2	−0.39	(-1.70,0.91)	0.760
		Bout1 − Bout3	−1.58	(-3.06,-0.11)	0.032
		Bout2 − Bout3	−1.19	(-2.67,0.29)	0.142
	S : 7v7	Bout1 − Bout2	0.07	(-1.26,1.41)	0.991
		Bout1 − Bout3	−0.49	(-1.84,0.85)	0.665
		Bout2 − Bout3	−0.57	(-1.91,0.78)	0.583
	M : 3v3	Bout1 − Bout2	−0.26	(-1.28,0.76)	0.820
		Bout1 − Bout3	0.52	(-0.53,1.58)	0.474
		Bout2 − Bout3	0.79	(-0.27,1.84)	0.189
	M : 5v5	Bout1 − Bout2	−0.24	(-1.91,1.44)	0.942
		Bout1 − Bout3	0.18	(-1.50,1.85)	0.967
		Bout2 − Bout3	0.41	(-1.27,2.09)	0.833

YOUTH	Pitch * No.	Comparison	Estimate	95% Adj. C.I.	Adj. *p*-value
	M : 7v7	Bout1 − Bout2	0.09	(-0.89,1.07)	0.974
		Bout1 − Bout3	0.22	(-0.76,1.21)	0.855
		Bout2 − Bout3	0.13	(-0.85,1.12)	0.946
	L : 3v3	Bout1 − Bout2	0.47	(-0.65,1.60)	0.583
		Bout1 − Bout3	0.49	(-0.64,1.62)	0.568
		Bout2 − Bout3	0.01	(-1.12,1.14)	1.000
	L : 5v5	Bout1 − Bout2	0.38	(-0.90,1.66)	0.767
		Bout1 − Bout3	0.69	(-0.59,1.97)	0.418
		Bout2 − Bout3	0.31	(-0.97,1.59)	0.838
	L : 7v7	Bout1 − Bout2	0.15	(-0.81,1.11)	0.925
		Bout1 − Bout3	−0.51	(-1.56,0.55)	0.496
		Bout2 − Bout3	−0.66	(-1.71,0.39)	0.304
AL_{3D} (AU)	S : 3v3	Bout1 − Bout2	0.04	(-0.46,0.55)	0.978
44 / 1004 Bouts with missing measurements.		Bout1 − Bout3	0.47	(-0.02,0.97)	0.063
		Bout2 − Bout3	0.43	(-0.07,0.93)	0.112
	S : 5v5	Bout1 − Bout2	−0.11	(-0.74,0.51)	0.909
		Bout1 − Bout3	−0.39	(-1.10,0.31)	0.390
		Bout2 − Bout3	−0.28	(-0.99,0.42)	0.615
	S : 7v7	Bout1 − Bout2	−0.04	(-0.68,0.60)	0.988
		Bout1 − Bout3	−0.02	(-0.66,0.61)	0.996
		Bout2 − Bout3	0.02	(-0.62,0.65)	0.997
	M : 3v3	Bout1 − Bout2	0.18	(-0.31,0.67)	0.660
		Bout1 − Bout3	0.52	(0.02,1.03)	0.041
		Bout2 − Bout3	0.34	(-0.16,0.85)	0.250
	M : 5v5	Bout1 − Bout2	0.45	(-0.38,1.28)	0.408
		Bout1 − Bout3	0.44	(-0.38,1.25)	0.415
		Bout2 − Bout3	−0.01	(-0.83,0.80)	0.999
	M : 7v7	Bout1 − Bout2	0.11	(-0.35,0.58)	0.836
		Bout1 − Bout3	−0.04	(-0.50,0.43)	0.982
		Bout2 − Bout3	−0.15	(-0.61,0.32)	0.732
	L : 3v3	Bout1 − Bout2	0.42	(-0.11,0.95)	0.153
		Bout1 − Bout3	0.71	(0.18,1.24)	0.005
		Bout2 − Bout3	0.29	(-0.24,0.82)	0.404
	L : 5v5	Bout1 − Bout2	0.25	(-0.37,0.87)	0.615
		Bout1 − Bout3	0.44	(-0.18,1.07)	0.219
		Bout2 − Bout3	0.19	(-0.43,0.82)	0.749
	L : 7v7	Bout1 − Bout2	0.33	(-0.13,0.79)	0.212
		Bout1 − Bout3	0.13	(-0.37,0.64)	0.806
		Bout2 − Bout3	−0.19	(-0.70,0.31)	0.634
Impact (min^{-1})	S : 3v3	Bout1 − Bout2	−0.01	(-0.05,0.02)	0.680
47 / 1004 Bouts with missing measurements.		Bout1 − Bout3	−0.01	(-0.05,0.03)	0.753
		Bout2 − Bout3	0.00	(-0.04,0.04)	0.990
	S : 5v5	Bout1 − Bout2	−0.02	(-0.06,0.03)	0.634
		Bout1 − Bout3	0.00	(-0.05,0.05)	1.000

YOUTH	Pitch * No.	Comparison	Estimate	95% Adj. C.I.	Adj. *p*-value
		Bout2 − Bout3	0.02	(-0.03,0.07)	0.700
	S : 7v7	Bout1 − Bout2	−0.02	(-0.07,0.03)	0.624
		Bout1 − Bout3	0.02	(-0.03,0.07)	0.641
		Bout2 − Bout3	0.04	(-0.01,0.08)	0.165
	M : 3v3	Bout1 − Bout2	−0.01	(-0.05,0.03)	0.758
		Bout1 − Bout3	−0.00	(-0.04,0.03)	0.977
		Bout2 − Bout3	0.01	(-0.03,0.04)	0.881
	M : 5v5	Bout1 − Bout2	−0.03	(-0.09,0.03)	0.473
		Bout1 − Bout3	−0.07	(-0.13,-0.01)	0.010
		Bout2 − Bout3	−0.04	(-0.10,0.02)	0.187
	M : 7v7	Bout1 − Bout2	−0.00	(-0.04,0.03)	0.946
		Bout1 − Bout3	−0.01	(-0.04,0.03)	0.937
		Bout2 − Bout3	−0.00	(-0.04,0.03)	1.000
	L : 3v3	Bout1 − Bout2	0.01	(-0.03,0.05)	0.715
		Bout1 − Bout3	0.01	(-0.03,0.05)	0.744
		Bout2 − Bout3	−0.00	(-0.04,0.04)	0.999
	L : 5v5	Bout1 − Bout2	−0.00	(-0.05,0.05)	1.000
		Bout1 − Bout3	0.01	(-0.04,0.05)	0.896
		Bout2 − Bout3	0.01	(-0.04,0.05)	0.896
	L : 7v7	Bout1 − Bout2	−0.04	(-0.07,-0.00)	0.021
		Bout1 − Bout3	−0.02	(-0.06,0.02)	0.405
		Bout2 − Bout3	0.02	(-0.02,0.06)	0.483
HIRD (m)	S : 3v3	Bout1 − Bout2	0.91	(-10.59,12.42)	0.981
101 / 1004 Bouts with missing measurements.		Bout1 − Bout3	0.43	(-10.76,11.62)	0.996
		Bout2 − Bout3	−0.48	(-12.05,11.09)	0.995
	S : 5v5	Bout1 − Bout2	−5.18	(-18.64,8.28)	0.638
		Bout1 − Bout3	−4.97	(-20.18,10.25)	0.724
		Bout2 − Bout3	0.21	(-15.01,15.43)	0.999
	S : 7v7	Bout1 − Bout2	4.54	(-9.43,18.51)	0.726
		Bout1 − Bout3	2.68	(-11.43,16.79)	0.896
		Bout2 − Bout3	−1.86	(-15.96,12.25)	0.949
	M : 3v3	Bout1 − Bout2	−2.48	(-13.22,8.26)	0.851
		Bout1 − Bout3	7.76	(-3.32,18.83)	0.228
		Bout2 − Bout3	10.23	(-0.84,21.31)	0.077
	M : 5v5	Bout1 − Bout2	0.94	(-16.87,18.75)	0.992
		Bout1 − Bout3	3.93	(-13.61,21.48)	0.858
		Bout2 − Bout3	3.00	(-14.55,20.54)	0.915
	M : 7v7	Bout1 − Bout2	−4.30	(-14.81,6.20)	0.601
		Bout1 − Bout3	−10.23	(-20.68,0.21)	0.056
		Bout2 − Bout3	−5.93	(-16.38,4.52)	0.377
	L : 3v3	Bout1 − Bout2	4.44	(-7.77,16.66)	0.670
		Bout1 − Bout3	6.24	(-5.98,18.45)	0.454
		Bout2 − Bout3	1.79	(-10.42,14.01)	0.937
	L : 5v5	Bout1 − Bout2	2.77	(-10.81,16.36)	0.881

YOUTH	Pitch * No.	Comparison	Estimate	95% Adj. C.I.	Adj. *p*-value
		Bout1 − Bout3	−1.62	(-15.21,11.96)	0.958
		Bout2 − Bout3	−4.39	(-17.85,9.07)	0.724
	L : 7v7	Bout1 − Bout2	6.52	(-3.55,16.59)	0.282
		Bout1 − Bout3	4.40	(-6.70,15.50)	0.621
		Bout2 − Bout3	−2.12	(-13.22,8.98)	0.895
HSRD (m)	S : 3v3	Bout1 − Bout2	0.97	(-8.29,10.24)	0.967
101 / 1004 Bouts with missing measurements.		Bout1 − Bout3	0.91	(-8.11,9.93)	0.970
		Bout2 − Bout3	−0.07	(-9.39,9.25)	1.000
	S : 5v5	Bout1 − Bout2	−3.79	(-14.63,7.06)	0.691
		Bout1 − Bout3	−2.10	(-14.36,10.16)	0.915
		Bout2 − Bout3	1.69	(-10.57,13.95)	0.944
	S : 7v7	Bout1 − Bout2	3.08	(-8.18,14.33)	0.797
		Bout1 − Bout3	1.96	(-9.41,13.33)	0.913
		Bout2 − Bout3	−1.11	(-12.48,10.25)	0.971
	M : 3v3	Bout1 − Bout2	−2.39	(-11.04,6.27)	0.794
		Bout1 − Bout3	4.97	(-3.95,13.90)	0.391
		Bout2 − Bout3	7.36	(-1.57,16.29)	0.129
	M : 5v5	Bout1 − Bout2	2.50	(-11.85,16.85)	0.912
		Bout1 − Bout3	1.90	(-12.24,16.03)	0.947
		Bout2 − Bout3	−0.60	(-14.74,13.53)	0.994
	M : 7v7	Bout1 − Bout2	−4.61	(-13.07,3.85)	0.408
		Bout1 − Bout3	−6.01	(-14.43,2.41)	0.215
		Bout2 − Bout3	−1.40	(-9.82,7.01)	0.919
	L : 3v3	Bout1 − Bout2	7.68	(-2.17,17.52)	0.160
		Bout1 − Bout3	7.91	(-1.93,17.76)	0.143
		Bout2 − Bout3	0.24	(-9.61,10.08)	0.998
	L : 5v5	Bout1 − Bout2	0.16	(-10.79,11.11)	0.999
		Bout1 − Bout3	−5.12	(-16.07,5.82)	0.515
		Bout2 − Bout3	−5.29	(-16.13,5.56)	0.487
	L : 7v7	Bout1 − Bout2	4.80	(-3.32,12.92)	0.347
		Bout1 − Bout3	4.01	(-4.93,12.96)	0.544
		Bout2 − Bout3	−0.79	(-9.73,8.16)	0.977
VHSRD (m)	S : 3v3	Bout1 − Bout2	−1.29	(-5.82,3.24)	0.783
103 / 1004 Bouts with missing measurements.		Bout1 − Bout3	−0.53	(-4.94,3.88)	0.957
		Bout2 − Bout3	0.76	(-3.80,5.31)	0.920
	S : 5v5	Bout1 − Bout2	−0.78	(-6.14,4.57)	0.937
		Bout1 − Bout3	−0.07	(-6.11,5.96)	1.000
		Bout2 − Bout3	0.71	(-5.28,6.70)	0.958
	S : 7v7	Bout1 − Bout2	0.50	(-5.00,6.00)	0.975
		Bout1 − Bout3	0.50	(-5.06,6.06)	0.976
		Bout2 − Bout3	−0.00	(-5.56,5.56)	1.000
	M : 3v3	Bout1 − Bout2	0.77	(-3.46,5.00)	0.904
		Bout1 − Bout3	1.83	(-2.53,6.20)	0.586
		Bout2 − Bout3	1.06	(-3.30,5.42)	0.836

YOUTH	Pitch * No.	Comparison	Estimate	95% Adj. C.I.	Adj. *p*-value
	M : 5v5	Bout1 − Bout2	0.94	(-6.08,7.95)	0.947
		Bout1 − Bout3	0.74	(-6.17,7.65)	0.966
		Bout2 − Bout3	−0.20	(-7.11,6.71)	0.997
	M : 7v7	Bout1 − Bout2	−1.50	(-5.64,2.64)	0.671
		Bout1 − Bout3	−0.45	(-4.57,3.66)	0.964
		Bout2 − Bout3	1.05	(-3.07,5.16)	0.821
	L : 3v3	Bout1 − Bout2	8.47	(3.66,13.28)	<0.001
		Bout1 − Bout3	6.44	(1.63,11.25)	0.005
		Bout2 − Bout3	−2.03	(-6.84,2.78)	0.583
	L : 5v5	Bout1 − Bout2	−1.40	(-6.75,3.95)	0.812
		Bout1 − Bout3	−3.04	(-8.40,2.31)	0.376
		Bout2 − Bout3	−1.64	(-6.95,3.66)	0.747
	L : 7v7	Bout1 − Bout2	1.23	(-2.76,5.22)	0.748
		Bout1 − Bout3	0.71	(-3.68,5.10)	0.924
		Bout2 − Bout3	−0.52	(-4.90,3.85)	0.957

U14	Pitch * No.	Comparison	Estimate	95% Adj. C.I.	Adj. *p*-value
TD (m)	S : 3v3	Bout1 − Bout2	48.10	(-36.14,132.34)	0.373
48 / 1004 Bouts with missing measurements.		Bout1 − Bout3	74.91	(0.62,149.20)	0.048
		Bout2 − Bout3	26.81	(-57.43,111.05)	0.735
	S : 5v5	Bout1 − Bout2	−23.90	(-101.82,54.02)	0.752
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	S : 7v7	Bout1 − Bout2	—		
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	M : 3v3	Bout1 − Bout2	−6.50	(-68.10,55.10)	0.967
		Bout1 − Bout3	−9.75	(-79.99,60.49)	0.943
		Bout2 − Bout3	−3.25	(-73.49,66.99)	0.994
	M : 5v5	Bout1 − Bout2	−22.60	(-100.52,55.32)	0.775
		Bout1 − Bout3	12.30	(-65.62,90.22)	0.927
		Bout2 − Bout3	34.90	(-43.02,112.82)	0.545
	M : 7v7	Bout1 − Bout2	−64.22	(-146.36,17.91)	0.159
		Bout1 − Bout3	−6.44	(-88.58,75.69)	0.981
		Bout2 − Bout3	57.78	(-24.36,139.91)	0.225
	L : 3v3	Bout1 − Bout2	23.10	(-59.55,105.75)	0.789
		Bout1 − Bout3	−90.50	(-173.15,-7.85)	0.028
		Bout2 − Bout3	−113.60	(-191.52,-35.68)	0.002
	L : 5v5	Bout1 − Bout2	—		
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	L : 7v7	Bout1 − Bout2	−8.86	(-74.71,57.00)	0.947
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
RD ($m \cdot min^{-1}$)	S : 3v3	Bout1 − Bout2	5.29	(-9.85,20.42)	0.691
47 / 1004 Bouts with missing measurements.		Bout1 − Bout3	15.09	(1.75,28.44)	0.022
		Bout2 − Bout3	9.81	(-5.33,24.94)	0.281
	S : 5v5	Bout1 − Bout2	−2.90	(-16.90,11.10)	0.878
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	S : 7v7	Bout1 − Bout2	—		
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	M : 3v3	Bout1 − Bout2	−2.25	(-13.32,8.82)	0.882
		Bout1 − Bout3	−4.70	(-17.32,7.92)	0.656
		Bout2 − Bout3	−2.45	(-15.07,10.17)	0.892
	M : 5v5	Bout1 − Bout2	−0.30	(-14.30,13.70)	0.999
		Bout1 − Bout3	7.10	(-6.90,21.10)	0.459
		Bout2 − Bout3	7.40	(-6.60,21.40)	0.429
	M : 7v7	Bout1 − Bout2	−15.22	(-29.98,-0.47)	0.041
		Bout1 − Bout3	−2.56	(-17.31,12.20)	0.913
		Bout2 − Bout3	12.67	(-2.09,27.42)	0.109

U14	Pitch * No.	Comparison	Estimate	95% Adj. C.I.	Adj. *p*-value
	L : 3v3	Bout1 − Bout2	16.52	(1.68,31.37)	0.025
		Bout1 − Bout3	30.92	(16.08,45.77)	<0.001
		Bout2 − Bout3	14.40	(0.40,28.40)	0.042
	L : 5v5	Bout1 − Bout2	—		
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	L : 7v7	Bout1 − Bout2	1.14	(-10.69,12.97)	0.972
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
V_{AVG} (km·h^{-1})	S : 3v3	Bout1 − Bout2	0.31	(-0.60,1.21)	0.711
47 / 1004 Bouts with		Bout1 − Bout3	0.89	(0.09,1.69)	0.025
missing measurements.		Bout2 − Bout3	0.59	(-0.32,1.50)	0.286
	S : 5v5	Bout1 − Bout2	−0.19	(-1.03,0.65)	0.857
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	S : 7v7	Bout1 − Bout2	—		
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	M : 3v3	Bout1 − Bout2	−0.14	(-0.80,0.53)	0.878
		Bout1 − Bout3	−0.28	(-1.04,0.48)	0.661
		Bout2 − Bout3	−0.14	(-0.90,0.62)	0.898
	M : 5v5	Bout1 − Bout2	−0.03	(-0.87,0.81)	0.996
		Bout1 − Bout3	0.43	(-0.41,1.27)	0.454
		Bout2 − Bout3	0.46	(-0.38,1.30)	0.405
	M : 7v7	Bout1 − Bout2	−0.91	(-1.80,-0.02)	0.042
		Bout1 − Bout3	−0.12	(-1.01,0.76)	0.944
		Bout2 − Bout3	0.79	(-0.10,1.68)	0.093
	L : 3v3	Bout1 − Bout2	0.96	(0.07,1.85)	0.031
		Bout1 − Bout3	1.84	(0.95,2.73)	<0.001
		Bout2 − Bout3	0.88	(0.04,1.72)	0.038
	L : 5v5	Bout1 − Bout2	—		
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	L : 7v7	Bout1 − Bout2	0.05	(-0.66,0.76)	0.985
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
V_{MAX} (km·h^{-1})	S : 3v3	Bout1 − Bout2	1.24	(-2.77,5.25)	0.750
47 / 1004 Bouts with		Bout1 − Bout3	−0.28	(-3.82,3.26)	0.981
missing measurements.		Bout2 − Bout3	−1.52	(-5.53,2.49)	0.648
	S : 5v5	Bout1 − Bout2	−3.01	(-6.72,0.70)	0.138
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	S : 7v7	Bout1 − Bout2	—		
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		

U14	Pitch * No.	Comparison	Estimate	95% Adj. C.I.	Adj. *p*-value
	M : 3v3	Bout1 − Bout2	−1.29	(-4.22,1.65)	0.558
		Bout1 − Bout3	−2.14	(-5.48,1.21)	0.291
		Bout2 − Bout3	−0.85	(-4.19,2.49)	0.822
	M : 5v5	Bout1 − Bout2	−0.96	(-4.67,2.75)	0.816
		Bout1 − Bout3	−0.51	(-4.22,3.20)	0.944
		Bout2 − Bout3	0.45	(-3.26,4.16)	0.956
	M : 7v7	Bout1 − Bout2	0.36	(-3.56,4.27)	0.975
		Bout1 − Bout3	−0.39	(-4.30,3.52)	0.970
		Bout2 − Bout3	−0.74	(-4.66,3.17)	0.896
	L : 3v3	Bout1 − Bout2	0.62	(-3.32,4.55)	0.928
		Bout1 − Bout3	1.27	(-2.67,5.20)	0.730
		Bout2 − Bout3	0.65	(-3.06,4.36)	0.911
	L : 5v5	Bout1 − Bout2	—		
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	L : 7v7	Bout1 − Bout2	0.33	(-2.81,3.46)	0.967
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
HRAVG (% HRMAX) *151 / 1004 Bouts with missing measurements.*	S : 3v3	Bout1 − Bout2	−1.90	(-10.56,6.76)	0.864
		Bout1 − Bout3	2.12	(-5.14,9.39)	0.771
		Bout2 − Bout3	4.02	(-4.79,12.84)	0.532
	S : 5v5	Bout1 − Bout2	−0.24	(-7.70,7.21)	0.997
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	S : 7v7	Bout1 − Bout2	—		
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	M : 3v3	Bout1 − Bout2	−0.73	(-7.06,5.60)	0.960
		Bout1 − Bout3	−7.43	(-14.65,-0.22)	0.042
		Bout2 − Bout3	−6.70	(-13.80,0.40)	0.069
	M : 5v5	Bout1 − Bout2	−2.85	(-10.76,5.06)	0.674
		Bout1 − Bout3	−0.70	(-8.61,7.21)	0.976
		Bout2 − Bout3	2.15	(-5.76,10.06)	0.799
	M : 7v7	Bout1 − Bout2	−9.11	(-17.02,-1.21)	0.019
		Bout1 − Bout3	−5.18	(-13.08,2.73)	0.274
		Bout2 − Bout3	3.94	(-3.97,11.84)	0.472
	L : 3v3	Bout1 − Bout2	−2.17	(-10.35,6.01)	0.808
		Bout1 − Bout3	0.79	(-7.39,8.98)	0.972
		Bout2 − Bout3	2.96	(-4.94,10.87)	0.653
	L : 5v5	Bout1 − Bout2	—		
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	L : 7v7	Bout1 − Bout2	−1.91	(-8.56,4.74)	0.778
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		

U14	Pitch * No.	Comparison	Estimate	95% Adj. C.I.	Adj. *p*-value
HRMAX (%HRMAX)	S : 3v3	Bout1 − Bout2	−5.84	(-13.98,2.30)	0.212
151 / 1004 Bouts with missing measurements.		Bout1 − Bout3	0.81	(-6.02,7.64)	0.958
		Bout2 − Bout3	6.65	(-1.65,14.94)	0.145
	S : 5v5	Bout1 − Bout2	0.99	(-6.02,8.00)	0.941
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	S : 7v7	Bout1 − Bout2	—		
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	M : 3v3	Bout1 − Bout2	−0.97	(-6.92,4.99)	0.923
		Bout1 − Bout3	−5.05	(-11.84,1.74)	0.188
		Bout2 − Bout3	−4.08	(-10.77,2.60)	0.323
	M : 5v5	Bout1 − Bout2	−1.80	(-9.23,5.63)	0.837
		Bout1 − Bout3	−0.69	(-8.12,6.75)	0.974
		Bout2 − Bout3	1.11	(-6.32,8.55)	0.934
	M : 7v7	Bout1 − Bout2	−8.58	(-16.01,-1.14)	0.019
		Bout1 − Bout3	−6.93	(-14.36,0.51)	0.074
		Bout2 − Bout3	1.65	(-5.78,9.08)	0.861
	L : 3v3	Bout1 − Bout2	0.41	(-7.29,8.10)	0.992
		Bout1 − Bout3	2.78	(-4.91,10.48)	0.673
		Bout2 − Bout3	2.37	(-5.06,9.81)	0.734
	L : 5v5	Bout1 − Bout2	—		
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	L : 7v7	Bout1 − Bout2	−3.50	(-9.75,2.76)	0.388
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
RPE (6-20)	S : 3v3	Bout1 − Bout2	−1.10	(-3.27,1.06)	0.455
2 / 1004 Bouts with missing measurements.		Bout1 − Bout3	−1.00	(-2.91,0.91)	0.436
		Bout2 − Bout3	0.10	(-2.06,2.27)	0.993
	S : 5v5	Bout1 − Bout2	−2.40	(-4.40,-0.40)	0.014
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	S : 7v7	Bout1 − Bout2	—		
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	M : 3v3	Bout1 − Bout2	−1.00	(-2.58,0.58)	0.300
		Bout1 − Bout3	−2.44	(-4.24,-0.63)	0.004
		Bout2 − Bout3	−1.44	(-3.24,0.37)	0.148
	M : 5v5	Bout1 − Bout2	−1.30	(-3.30,0.70)	0.280
		Bout1 − Bout3	−3.10	(-5.10,-1.10)	<0.001
		Bout2 − Bout3	−1.80	(-3.80,0.20)	0.088
	M : 7v7	Bout1 − Bout2	−1.92	(-3.68,-0.17)	0.028
		Bout1 − Bout3	−1.31	(-3.11,0.48)	0.198
		Bout2 − Bout3	0.61	(-1.18,2.40)	0.705

U14	Pitch * No.	Comparison	Estimate	95% Adj. C.I.	Adj. *p*-value
	L : 3v3	Bout1 − Bout2	−1.90	(-3.86,0.06)	0.059
		Bout1 − Bout3	−2.35	(-4.31,-0.40)	0.013
		Bout2 − Bout3	−0.45	(-2.36,1.46)	0.842
	L : 5v5	Bout1 − Bout2	—		
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	L : 7v7	Bout1 − Bout2	−2.21	(-3.91,-0.52)	0.006
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
Sprint·min^{-1}	S : 3v3	Bout1 − Bout2	0.50	(-0.76,1.76)	0.616
47 / 1004 Bouts with missing measurements.		Bout1 − Bout3	0.73	(-0.38,1.84)	0.274
		Bout2 − Bout3	0.22	(-1.04,1.48)	0.908
	S : 5v5	Bout1 − Bout2	0.03	(-1.14,1.19)	0.999
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	S : 7v7	Bout1 − Bout2	—		
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	M : 3v3	Bout1 − Bout2	0.05	(-0.87,0.97)	0.992
		Bout1 − Bout3	−0.35	(-1.40,0.70)	0.714
		Bout2 − Bout3	−0.40	(-1.45,0.65)	0.648
	M : 5v5	Bout1 − Bout2	0.18	(-0.99,1.34)	0.934
		Bout1 − Bout3	0.45	(-0.71,1.61)	0.636
		Bout2 − Bout3	0.27	(-0.89,1.44)	0.844
	M : 7v7	Bout1 − Bout2	−0.64	(-1.87,0.59)	0.441
		Bout1 − Bout3	−0.08	(-1.31,1.14)	0.986
		Bout2 − Bout3	0.56	(-0.67,1.78)	0.538
	L : 3v3	Bout1 − Bout2	0.34	(-0.89,1.58)	0.791
		Bout1 − Bout3	0.94	(-0.29,2.18)	0.172
		Bout2 − Bout3	0.60	(-0.56,1.76)	0.448
	L : 5v5	Bout1 − Bout2	—		
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	L : 7v7	Bout1 − Bout2	−0.05	(-1.04,0.93)	0.991
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
HIacc	S : 3v3	Bout1 − Bout2	0.90	(-3.89,5.68)	0.899
47 / 1004 Bouts with missing measurements.		Bout1 − Bout3	2.45	(-1.76,6.67)	0.359
		Bout2 − Bout3	1.56	(-3.23,6.34)	0.725
	S : 5v5	Bout1 − Bout2	1.10	(-3.32,5.52)	0.829
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	S : 7v7	Bout1 − Bout2	—		
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		

U14	Pitch * No.	Comparison	Estimate	95% Adj. C.I.	Adj. *p*-value
	M : 3v3	Bout1 − Bout2	2.44	(-1.06,5.94)	0.231
		Bout1 − Bout3	−0.76	(-4.75,3.23)	0.895
		Bout2 − Bout3	−3.20	(-7.19,0.79)	0.144
	M : 5v5	Bout1 − Bout2	0.90	(-3.52,5.32)	0.882
		Bout1 − Bout3	2.10	(-2.32,6.52)	0.506
		Bout2 − Bout3	1.20	(-3.22,5.62)	0.800
	M : 7v7	Bout1 − Bout2	−1.00	(-5.66,3.66)	0.870
		Bout1 − Bout3	2.33	(-2.33,7.00)	0.469
		Bout2 − Bout3	3.33	(-1.33,8.00)	0.214
	L : 3v3	Bout1 − Bout2	4.65	(-0.04,9.34)	0.053
		Bout1 − Bout3	3.05	(-1.64,7.74)	0.279
		Bout2 − Bout3	−1.60	(-6.02,2.82)	0.673
	L : 5v5	Bout1 − Bout2	—		
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	L : 7v7	Bout1 − Bout2	0.93	(-2.81,4.67)	0.829
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
HIdec	S : 3v3	Bout1 − Bout2	0.52	(-1.76,2.80)	0.854
47 / 1004 Bouts with missing measurements.		Bout1 − Bout3	0.36	(-1.65,2.37)	0.905
		Bout2 − Bout3	−0.16	(-2.44,2.12)	0.986
	S : 5v5	Bout1 − Bout2	0.10	(-2.01,2.21)	0.993
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	S : 7v7	Bout1 − Bout2	—		
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	M : 3v3	Bout1 − Bout2	−1.12	(-2.79,0.54)	0.253
		Bout1 − Bout3	−0.86	(-2.76,1.04)	0.536
		Bout2 − Bout3	0.26	(-1.64,2.16)	0.944
	M : 5v5	Bout1 − Bout2	−0.20	(-2.31,1.91)	0.973
		Bout1 − Bout3	0.60	(-1.51,2.71)	0.782
		Bout2 − Bout3	0.80	(-1.31,2.91)	0.646
	M : 7v7	Bout1 − Bout2	−0.89	(-3.11,1.33)	0.616
		Bout1 − Bout3	−0.56	(-2.78,1.67)	0.827
		Bout2 − Bout3	0.33	(-1.89,2.56)	0.934
	L : 3v3	Bout1 − Bout2	1.52	(-0.71,3.76)	0.246
		Bout1 − Bout3	0.82	(-1.41,3.06)	0.662
		Bout2 − Bout3	−0.70	(-2.81,1.41)	0.716
	L : 5v5	Bout1 − Bout2	—		
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	L : 7v7	Bout1 − Bout2	−0.29	(-2.07,1.50)	0.925
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		

U14	Pitch * No.	Comparison	Estimate	95% Adj. C.I.	Adj. *p*-value
AL_{3D} (AU)	S : 3v3	Bout1 − Bout2	0.10	(-0.94,1.13)	0.974
44 / 1004 Bouts with missing measurements.		Bout1 − Bout3	0.69	(-0.22,1.60)	0.178
		Bout2 − Bout3	0.59	(-0.44,1.63)	0.369
	S : 5v5	Bout1 − Bout2	0.16	(-0.80,1.12)	0.919
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	S : 7v7	Bout1 − Bout2	—		
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	M : 3v3	Bout1 − Bout2	0.06	(-0.69,0.82)	0.980
		Bout1 − Bout3	−0.06	(-0.92,0.81)	0.987
		Bout2 − Bout3	−0.12	(-0.98,0.74)	0.943
	M : 5v5	Bout1 − Bout2	0.23	(-0.73,1.19)	0.839
		Bout1 − Bout3	0.54	(-0.42,1.50)	0.382
		Bout2 − Bout3	0.31	(-0.65,1.27)	0.728
	M : 7v7	Bout1 − Bout2	−0.82	(-1.83,0.19)	0.136
		Bout1 − Bout3	−0.19	(-1.20,0.82)	0.899
		Bout2 − Bout3	0.63	(-0.38,1.64)	0.304
	L : 3v3	Bout1 − Bout2	0.53	(-0.41,1.46)	0.385
		Bout1 − Bout3	1.29	(0.35,2.22)	0.004
		Bout2 − Bout3	0.76	(-0.15,1.68)	0.122
	L : 5v5	Bout1 − Bout2	—		
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	L : 7v7	Bout1 − Bout2	0.13	(-0.68,0.94)	0.926
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
Impact (min^{-1})	S : 3v3	Bout1 − Bout2	−0.04	(-0.12,0.05)	0.572
47 / 1004 Bouts with missing measurements.		Bout1 − Bout3	−0.02	(-0.10,0.05)	0.747
		Bout2 − Bout3	0.01	(-0.07,0.10)	0.929
	S : 5v5	Bout1 − Bout2	−0.03	(-0.10,0.05)	0.726
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	S : 7v7	Bout1 − Bout2	—		
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	M : 3v3	Bout1 − Bout2	−0.02	(-0.08,0.05)	0.818
		Bout1 − Bout3	0.03	(-0.04,0.10)	0.540
		Bout2 − Bout3	0.05	(-0.02,0.12)	0.251
	M : 5v5	Bout1 − Bout2	−0.05	(-0.13,0.03)	0.279
		Bout1 − Bout3	−0.08	(-0.15,0.00)	0.058
		Bout2 − Bout3	−0.02	(-0.10,0.05)	0.726
	M : 7v7	Bout1 − Bout2	−0.03	(-0.11,0.05)	0.700
		Bout1 − Bout3	−0.03	(-0.11,0.05)	0.700
		Bout2 − Bout3	0.00	(-0.08,0.08)	1.000

U14	Pitch * No.	Comparison	Estimate	95% Adj. C.I.	Adj. *p*-value
	L : 3v3	Bout1 − Bout2	0.04	(-0.04,0.12)	0.527
		Bout1 − Bout3	0.04	(-0.04,0.12)	0.527
		Bout2 − Bout3	0.00	(-0.08,0.08)	1.000
	L : 5v5	Bout1 − Bout2	—		
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	L : 7v7	Bout1 − Bout2	−0.05	(-0.12,0.01)	0.129
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
HIRD (m)	S : 3v3	Bout1 − Bout2	7.18	(-17.79,32.15)	0.778
101 / 1004 Bouts with missing measurements.		Bout1 − Bout3	4.08	(-17.41,25.58)	0.896
		Bout2 − Bout3	−3.10	(-28.51,22.31)	0.956
	S : 5v5	Bout1 − Bout2	−8.30	(-30.30,13.70)	0.649
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	S : 7v7	Bout1 − Bout2	—		
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	M : 3v3	Bout1 − Bout2	−7.36	(-25.95,11.24)	0.622
		Bout1 − Bout3	−1.54	(-22.56,19.48)	0.984
		Bout2 − Bout3	5.82	(-15.20,26.84)	0.793
	M : 5v5	Bout1 − Bout2	−4.90	(-26.90,17.10)	0.860
		Bout1 − Bout3	−1.00	(-23.00,21.00)	0.994
		Bout2 − Bout3	3.90	(-18.10,25.90)	0.909
	M : 7v7	Bout1 − Bout2	−2.50	(-27.10,22.10)	0.969
		Bout1 − Bout3	−8.13	(-32.72,16.47)	0.718
		Bout2 − Bout3	−5.62	(-30.22,18.97)	0.853
	L : 3v3	Bout1 − Bout2	17.42	(-9.15,43.99)	0.273
		Bout1 − Bout3	31.67	(5.10,58.24)	0.015
		Bout2 − Bout3	14.25	(-10.35,38.85)	0.362
	L : 5v5	Bout1 − Bout2	—		
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	L : 7v7	Bout1 − Bout2	2.07	(-16.52,20.67)	0.963
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
HSRD (m)	S : 3v3	Bout1 − Bout2	7.21	(-13.09,27.51)	0.682
101 / 1004 Bouts with missing measurements.		Bout1 − Bout3	4.85	(-12.63,22.32)	0.792
		Bout2 − Bout3	−2.37	(-23.02,18.29)	0.961
	S : 5v5	Bout1 − Bout2	−6.60	(-24.49,11.29)	0.662
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	S : 7v7	Bout1 − Bout2	—		
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		

U14	Pitch * No.	Comparison	Estimate	95% Adj. C.I.	Adj. *p*-value
	M : 3v3	Bout1 − Bout2	−3.57	(-18.69,11.55)	0.844
		Bout1 − Bout3	−1.21	(-18.31,15.88)	0.985
		Bout2 − Bout3	2.36	(-14.73,19.45)	0.944
	M : 5v5	Bout1 − Bout2	−0.90	(-18.79,16.99)	0.992
		Bout1 − Bout3	−1.00	(-18.89,16.89)	0.991
		Bout2 − Bout3	−0.10	(-17.99,17.79)	1.000
	M : 7v7	Bout1 − Bout2	−2.38	(-22.38,17.63)	0.958
		Bout1 − Bout3	−3.38	(-23.38,16.63)	0.917
		Bout2 − Bout3	−1.00	(-21.00,19.00)	0.992
	L : 3v3	Bout1 − Bout2	21.67	(0.06,43.27)	0.049
		Bout1 − Bout3	38.79	(17.19,60.40)	<0.001
		Bout2 − Bout3	17.12	(-2.88,37.13)	0.110
	L : 5v5	Bout1 − Bout2	—		
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	L : 7v7	Bout1 − Bout2	2.29	(-12.83,17.41)	0.933
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
VHSRD (m)	S : 3v3	Bout1 − Bout2	0.00	(-9.96,9.96)	1.000
103 / 1004 Bouts with missing measurements.		Bout1 − Bout3	0.00	(-8.57,8.57)	1.000
		Bout2 − Bout3	−0.00	(-10.13,10.13)	1.000
	S : 5v5	Bout1 − Bout2	−2.10	(-10.88,6.68)	0.840
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	S : 7v7	Bout1 − Bout2	—		
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	M : 3v3	Bout1 − Bout2	−0.71	(-8.13,6.70)	0.972
		Bout1 − Bout3	−0.15	(-8.53,8.23)	0.999
		Bout2 − Bout3	0.56	(-7.82,8.95)	0.986
	M : 5v5	Bout1 − Bout2	−0.90	(-9.68,7.88)	0.969
		Bout1 − Bout3	−2.40	(-11.18,6.38)	0.797
		Bout2 − Bout3	−1.50	(-10.28,7.28)	0.915
	M : 7v7	Bout1 − Bout2	0.00	(-9.81,9.81)	1.000
		Bout1 − Bout3	0.00	(-9.81,9.81)	1.000
		Bout2 − Bout3	0.00	(-9.81,9.81)	1.000
	L : 3v3	Bout1 − Bout2	23.67	(13.07,34.26)	<0.001
		Bout1 − Bout3	21.67	(11.07,32.26)	<0.001
		Bout2 − Bout3	−2.00	(-11.81,7.81)	0.881
	L : 5v5	Bout1 − Bout2	—		
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	L : 7v7	Bout1 − Bout2	1.64	(-5.77,9.06)	0.862
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		

U15	Pitch * No.	Comparison	Estimate	95% Adj. C.I.	Adj. *p*-value
TD (m)	S : 3v3	Bout1 − Bout2	18.60	(-91.59,128.79)	0.917
48 / 1004 Bouts with missing measurements.		Bout1 − Bout3	50.00	(-60.19,160.19)	0.536
		Bout2 − Bout3	31.40	(-78.79,141.59)	0.782
	S : 5v5	Bout1 − Bout2	−3.70	(-81.62,74.22)	0.993
		Bout1 − Bout3	−19.10	(-97.02,58.82)	0.833
		Bout2 − Bout3	−15.40	(-93.32,62.52)	0.888
	S : 7v7	Bout1 − Bout2	5.31	(-63.03,73.65)	0.982
		Bout1 − Bout3	27.65	(-42.09,97.40)	0.621
		Bout2 − Bout3	22.35	(-47.40,92.09)	0.732
	M : 3v3	Bout1 − Bout2	−3.67	(-104.26,96.93)	0.996
		Bout1 − Bout3	88.17	(-12.43,188.76)	0.099
		Bout2 − Bout3	91.83	(-8.76,192.43)	0.082
	M : 5v5	Bout1 − Bout2	—		
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	M : 7v7	Bout1 − Bout2	19.30	(-28.58,67.17)	0.611
		Bout1 − Bout3	−31.38	(-79.71,16.94)	0.280
		Bout2 − Bout3	−50.68	(-98.55,-2.81)	0.035
	L : 3v3	Bout1 − Bout2	39.03	(-66.47,144.54)	0.660
		Bout1 − Bout3	65.43	(-40.07,170.94)	0.313
		Bout2 − Bout3	26.40	(-83.79,136.59)	0.840
	L : 5v5	Bout1 − Bout2	28.10	(-49.82,106.02)	0.674
		Bout1 − Bout3	52.50	(-25.42,130.42)	0.254
		Bout2 − Bout3	24.40	(-53.52,102.32)	0.743
	L : 7v7	Bout1 − Bout2	19.01	(-48.10,86.12)	0.784
		Bout1 − Bout3	24.50	(-41.35,90.35)	0.657
		Bout2 − Bout3	5.49	(-61.62,72.60)	0.980
RD ($m \cdot min^{-1}$)	S : 3v3	Bout1 − Bout2	5.80	(-13.99,25.59)	0.771
47 / 1004 Bouts with missing measurements.		Bout1 − Bout3	12.60	(-7.19,32.39)	0.294
		Bout2 − Bout3	6.80	(-12.99,26.59)	0.699
	S : 5v5	Bout1 − Bout2	−1.00	(-15.00,13.00)	0.985
		Bout1 − Bout3	−4.70	(-18.70,9.30)	0.710
		Bout2 − Bout3	−3.70	(-17.70,10.30)	0.809
	S : 7v7	Bout1 − Bout2	−4.00	(-16.28,8.28)	0.725
		Bout1 − Bout3	−2.09	(-14.62,10.44)	0.919
		Bout2 − Bout3	1.91	(-10.62,14.44)	0.932
	M : 3v3	Bout1 − Bout2	4.83	(-13.24,22.90)	0.805
		Bout1 − Bout3	22.50	(4.43,40.57)	0.010
		Bout2 − Bout3	17.67	(-0.40,35.74)	0.057
	M : 5v5	Bout1 − Bout2	—		
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	M : 7v7	Bout1 − Bout2	6.66	(-1.94,15.26)	0.164
		Bout1 − Bout3	−5.65	(-14.33,3.03)	0.278

U15	Pitch * No.	Comparison	Estimate	95% Adj. C.I.	Adj. *p*-value
		Bout2 − Bout3	−12.32	(-20.92,-3.72)	0.002
	L : 3v3	Bout1 − Bout2	10.40	(-8.55,29.35)	0.402
		Bout1 − Bout3	15.60	(-3.35,34.55)	0.130
		Bout2 − Bout3	5.20	(-14.59,24.99)	0.811
	L : 5v5	Bout1 − Bout2	2.90	(-11.10,16.90)	0.878
		Bout1 − Bout3	10.20	(-3.80,24.20)	0.202
		Bout2 − Bout3	7.30	(-6.70,21.30)	0.439
	L : 7v7	Bout1 − Bout2	3.93	(-7.90,15.76)	0.716
		Bout1 − Bout3	4.64	(-7.19,16.47)	0.627
		Bout2 − Bout3	0.71	(-11.12,12.54)	0.989
V_{AVG} (km·h^{-1})	S : 3v3	Bout1 − Bout2	0.38	(-0.81,1.57)	0.734
47 / 1004 Bouts with missing measurements.		Bout1 − Bout3	0.76	(-0.43,1.95)	0.292
		Bout2 − Bout3	0.38	(-0.81,1.57)	0.734
	S : 5v5	Bout1 − Bout2	−0.05	(-0.89,0.79)	0.989
		Bout1 − Bout3	−0.27	(-1.11,0.57)	0.732
		Bout2 − Bout3	−0.22	(-1.06,0.62)	0.813
	S : 7v7	Bout1 − Bout2	−0.25	(-0.98,0.49)	0.713
		Bout1 − Bout3	−0.13	(-0.88,0.63)	0.918
		Bout2 − Bout3	0.12	(-0.63,0.87)	0.926
	M : 3v3	Bout1 − Bout2	0.27	(-0.82,1.35)	0.833
		Bout1 − Bout3	1.33	(0.25,2.42)	0.011
		Bout2 − Bout3	1.07	(-0.02,2.15)	0.056
	M : 5v5	Bout1 − Bout2	—		
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	M : 7v7	Bout1 − Bout2	0.40	(-0.12,0.92)	0.166
		Bout1 − Bout3	−0.34	(-0.86,0.18)	0.273
		Bout2 − Bout3	−0.74	(-1.26,-0.22)	0.002
	L : 3v3	Bout1 − Bout2	0.64	(-0.50,1.78)	0.381
		Bout1 − Bout3	0.96	(-0.18,2.10)	0.116
		Bout2 − Bout3	0.32	(-0.87,1.51)	0.803
	L : 5v5	Bout1 − Bout2	0.15	(-0.69,0.99)	0.908
		Bout1 − Bout3	0.58	(-0.26,1.42)	0.238
		Bout2 − Bout3	0.43	(-0.41,1.27)	0.454
	L : 7v7	Bout1 − Bout2	0.24	(-0.48,0.95)	0.716
		Bout1 − Bout3	0.26	(-0.45,0.97)	0.673
		Bout2 − Bout3	0.02	(-0.69,0.73)	0.997
V_{MAX} (km·h^{-1})	S : 3v3	Bout1 − Bout2	−0.62	(-5.87,4.63)	0.958
47 / 1004 Bouts with missing measurements.		Bout1 − Bout3	2.68	(-2.57,7.93)	0.454
		Bout2 − Bout3	3.30	(-1.95,8.55)	0.303
	S : 5v5	Bout1 − Bout2	−0.23	(-3.94,3.48)	0.988
		Bout1 − Bout3	−0.84	(-4.55,2.87)	0.856
		Bout2 − Bout3	−0.61	(-4.32,3.10)	0.921
	S : 7v7	Bout1 − Bout2	2.30	(-0.95,5.55)	0.222

U15	Pitch * No.	Comparison	Estimate	95% Adj. C.I.	Adj. *p*-value
		Bout1 − Bout3	0.98	(-2.34,4.30)	0.768
		Bout2 − Bout3	−1.32	(-4.64,2.00)	0.619
	M : 3v3	Bout1 − Bout2	−1.88	(-6.67,2.91)	0.626
		Bout1 − Bout3	−1.60	(-6.39,3.19)	0.713
		Bout2 − Bout3	0.28	(-4.51,5.07)	0.989
	M : 5v5	Bout1 − Bout2	—		
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	M : 7v7	Bout1 − Bout2	−0.07	(-2.34,2.21)	0.997
		Bout1 − Bout3	−0.92	(-3.22,1.38)	0.614
		Bout2 − Bout3	−0.86	(-3.14,1.42)	0.651
	L : 3v3	Bout1 − Bout2	0.19	(-4.83,5.22)	0.996
		Bout1 − Bout3	−1.27	(-6.29,3.76)	0.824
		Bout2 − Bout3	−1.46	(-6.71,3.79)	0.791
	L : 5v5	Bout1 − Bout2	0.71	(-3.00,4.42)	0.895
		Bout1 − Bout3	1.41	(-2.30,5.12)	0.645
		Bout2 − Bout3	0.70	(-3.01,4.41)	0.898
	L : 7v7	Bout1 − Bout2	0.47	(-2.66,3.61)	0.934
		Bout1 − Bout3	0.66	(-2.47,3.80)	0.873
		Bout2 − Bout3	0.19	(-2.94,3.33)	0.989
HR_{AVG} (% HR_{MAX})	S : 3v3	Bout1 − Bout2	−5.68	(-15.68,4.32)	0.377
151 / 1004 Bouts with missing measurements.		Bout1 − Bout3	−4.04	(-14.04,5.96)	0.610
		Bout2 − Bout3	1.64	(-8.36,11.64)	0.922
	S : 5v5	Bout1 − Bout2	0.41	(-7.09,7.91)	0.991
		Bout1 − Bout3	−4.50	(-12.00,3.00)	0.337
		Bout2 − Bout3	−4.91	(-11.98,2.16)	0.233
	S : 7v7	Bout1 − Bout2	−1.46	(-8.53,5.61)	0.879
		Bout1 − Bout3	−1.51	(-8.78,5.75)	0.876
		Bout2 − Bout3	−0.05	(-7.32,7.21)	1.000
	M : 3v3	Bout1 − Bout2	−7.07	(-19.98,5.84)	0.404
		Bout1 − Bout3	−5.07	(-17.98,7.84)	0.627
		Bout2 − Bout3	2.00	(-10.91,14.91)	0.930
	M : 5v5	Bout1 − Bout2	—		
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	M : 7v7	Bout1 − Bout2	1.33	(-3.29,5.94)	0.778
		Bout1 − Bout3	−1.68	(-6.35,2.98)	0.674
		Bout2 − Bout3	−3.01	(-7.62,1.61)	0.277
	L : 3v3	Bout1 − Bout2	−7.84	(-17.84,2.16)	0.157
		Bout1 − Bout3	−0.36	(-10.36,9.64)	0.996
		Bout2 − Bout3	7.48	(-2.52,17.48)	0.185
	L : 5v5	Bout1 − Bout2	−4.20	(-11.65,3.25)	0.383
		Bout1 − Bout3	−2.48	(-9.93,4.98)	0.715

U15	Pitch * No.	Comparison	Estimate	95% Adj. C.I.	Adj. *p*-value
		Bout2 − Bout3	1.72	(-5.73,9.18)	0.850
	L : 7v7	Bout1 − Bout2	−4.24	(-10.57,2.09)	0.257
		Bout1 − Bout3	−1.77	(-8.10,4.56)	0.789
		Bout2 − Bout3	2.48	(-3.72,8.68)	0.616
HRMAX (%HRMAX) *151 / 1004 Bouts with missing measurements.*	S : 3v3	Bout1 − Bout2	−1.48	(-10.88,7.92)	0.927
		Bout1 − Bout3	−0.02	(-9.42,9.38)	1.000
		Bout2 − Bout3	1.46	(-7.94,10.86)	0.929
	S : 5v5	Bout1 − Bout2	0.58	(-6.47,7.64)	0.979
		Bout1 − Bout3	−4.10	(-11.15,2.96)	0.361
		Bout2 − Bout3	−4.68	(-11.33,1.97)	0.224
	S : 7v7	Bout1 − Bout2	−2.32	(-8.97,4.33)	0.691
		Bout1 − Bout3	0.94	(-5.89,7.77)	0.944
		Bout2 − Bout3	3.26	(-3.57,10.09)	0.501
	M : 3v3	Bout1 − Bout2	−3.03	(-15.17,9.11)	0.827
		Bout1 − Bout3	−4.20	(-16.34,7.94)	0.695
		Bout2 − Bout3	−1.17	(-13.31,10.97)	0.972
	M : 5v5	Bout1 − Bout2	—		
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	M : 7v7	Bout1 − Bout2	1.48	(-2.86,5.82)	0.703
		Bout1 − Bout3	−1.86	(-6.24,2.53)	0.581
		Bout2 − Bout3	−3.33	(-7.67,1.00)	0.169
	L : 3v3	Bout1 − Bout2	−1.08	(-10.48,8.32)	0.961
		Bout1 − Bout3	1.10	(-8.30,10.50)	0.959
		Bout2 − Bout3	2.18	(-7.22,11.58)	0.849
	L : 5v5	Bout1 − Bout2	−1.79	(-8.80,5.22)	0.820
		Bout1 − Bout3	−1.61	(-8.62,5.40)	0.852
		Bout2 − Bout3	0.18	(-6.83,7.19)	0.998
	L : 7v7	Bout1 − Bout2	−0.04	(-5.99,5.91)	1.000
		Bout1 − Bout3	0.62	(-5.34,6.57)	0.968
		Bout2 − Bout3	0.65	(-5.18,6.49)	0.963
RPE (6-20) *2 / 1004 Bouts with missing measurements.*	S : 3v3	Bout1 − Bout2	−1.00	(-3.59,1.59)	0.635
		Bout1 − Bout3	−0.50	(-3.09,2.09)	0.893
		Bout2 − Bout3	0.50	(-2.09,3.09)	0.893
	S : 5v5	Bout1 − Bout2	−0.70	(-2.70,1.30)	0.690
		Bout1 − Bout3	−2.00	(-4.00,0.00)	0.050
		Bout2 − Bout3	−1.30	(-3.30,0.70)	0.280
	S : 7v7	Bout1 − Bout2	−0.15	(-1.91,1.60)	0.977
		Bout1 − Bout3	−1.00	(-2.76,0.76)	0.375
		Bout2 − Bout3	−0.85	(-2.60,0.91)	0.495
	M : 3v3	Bout1 − Bout2	−1.00	(-3.59,1.59)	0.635
		Bout1 − Bout3	−1.17	(-3.75,1.42)	0.540
		Bout2 − Bout3	−0.17	(-2.75,2.42)	0.987

U15	Pitch * No.	Comparison	Estimate	95% Adj. C.I.	Adj. *p*-value
	M : 5v5	Bout1 − Bout2	—		
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	M : 7v7	Bout1 − Bout2	−0.11	(-1.30,1.08)	0.974
		Bout1 − Bout3	−1.50	(-2.70,-0.30)	0.009
		Bout2 − Bout3	−1.39	(-2.58,-0.20)	0.017
	L : 3v3	Bout1 − Bout2	−0.50	(-3.09,2.09)	0.893
		Bout1 − Bout3	−0.67	(-3.25,1.92)	0.817
		Bout2 − Bout3	−0.17	(-2.75,2.42)	0.987
	L : 5v5	Bout1 − Bout2	−0.50	(-2.50,1.50)	0.828
		Bout1 − Bout3	−1.20	(-3.20,0.80)	0.338
		Bout2 − Bout3	−0.70	(-2.70,1.30)	0.690
	L : 7v7	Bout1 − Bout2	−1.00	(-2.69,0.69)	0.348
		Bout1 − Bout3	−1.14	(-2.84,0.55)	0.253
		Bout2 − Bout3	−0.14	(-1.84,1.55)	0.979
Sprint·min^{-1}	S : 3v3	Bout1 − Bout2	0.30	(-1.35,1.95)	0.904
47 / 1004 Bouts with missing measurements.		Bout1 − Bout3	1.20	(-0.45,2.85)	0.202
		Bout2 − Bout3	0.90	(-0.75,2.55)	0.405
	S : 5v5	Bout1 − Bout2	0.20	(-0.96,1.36)	0.914
		Bout1 − Bout3	0.02	(-1.14,1.19)	0.999
		Bout2 − Bout3	−0.18	(-1.34,0.99)	0.934
	S : 7v7	Bout1 − Bout2	−0.29	(-1.31,0.73)	0.785
		Bout1 − Bout3	−0.08	(-1.13,0.96)	0.980
		Bout2 − Bout3	0.20	(-0.84,1.25)	0.891
	M : 3v3	Bout1 − Bout2	0.08	(-1.42,1.59)	0.991
		Bout1 − Bout3	0.96	(-0.55,2.46)	0.293
		Bout2 − Bout3	0.87	(-0.63,2.38)	0.359
	M : 5v5	Bout1 − Bout2	—		
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	M : 7v7	Bout1 − Bout2	0.20	(-0.52,0.91)	0.795
		Bout1 − Bout3	−0.07	(-0.79,0.66)	0.974
		Bout2 − Bout3	−0.26	(-0.98,0.45)	0.662
	L : 3v3	Bout1 − Bout2	0.24	(-1.34,1.82)	0.931
		Bout1 − Bout3	0.94	(-0.64,2.52)	0.340
		Bout2 − Bout3	0.70	(-0.95,2.35)	0.579
	L : 5v5	Bout1 − Bout2	0.15	(-1.01,1.31)	0.951
		Bout1 − Bout3	0.52	(-0.64,1.69)	0.540
		Bout2 − Bout3	0.37	(-0.79,1.54)	0.730
	L : 7v7	Bout1 − Bout2	0.02	(-0.97,1.00)	0.999
		Bout1 − Bout3	0.25	(-0.73,1.23)	0.822
		Bout2 − Bout3	0.23	(-0.75,1.22)	0.845
HIacc	S : 3v3	Bout1 − Bout2	3.40	(-2.86,9.66)	0.409
		Bout1 − Bout3	5.60	(-0.66,11.86)	0.090

U15	Pitch * No.	Comparison	Estimate	95% Adj. C.I.	Adj. *p*-value
47 / 1004 Bouts with missing measurements.		Bout2 − Bout3	2.20	(-4.06,8.46)	0.687
	S : 5v5	Bout1 − Bout2	2.70	(-1.72,7.12)	0.325
		Bout1 − Bout3	0.80	(-3.62,5.22)	0.905
		Bout2 − Bout3	−1.90	(-6.32,2.52)	0.572
	S : 7v7	Bout1 − Bout2	−1.08	(-4.96,2.80)	0.792
		Bout1 − Bout3	0.05	(-3.91,4.01)	0.999
		Bout2 − Bout3	1.13	(-2.83,5.09)	0.782
	M : 3v3	Bout1 − Bout2	1.83	(-3.88,7.55)	0.732
		Bout1 − Bout3	3.67	(-2.05,9.38)	0.288
		Bout2 − Bout3	1.83	(-3.88,7.55)	0.732
	M : 5v5	Bout1 − Bout2	—		
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	M : 7v7	Bout1 − Bout2	0.21	(-2.51,2.92)	0.983
		Bout1 − Bout3	0.04	(-2.71,2.78)	0.999
		Bout2 − Bout3	−0.17	(-2.89,2.55)	0.989
	L : 3v3	Bout1 − Bout2	−1.37	(-7.36,4.62)	0.854
		Bout1 − Bout3	2.83	(-3.16,8.82)	0.508
		Bout2 − Bout3	4.20	(-2.06,10.46)	0.257
	L : 5v5	Bout1 − Bout2	0.50	(-3.92,4.92)	0.962
		Bout1 − Bout3	1.30	(-3.12,5.72)	0.770
		Bout2 − Bout3	0.80	(-3.62,5.22)	0.905
	L : 7v7	Bout1 − Bout2	0.93	(-2.81,4.67)	0.829
		Bout1 − Bout3	1.79	(-1.95,5.53)	0.501
		Bout2 − Bout3	0.86	(-2.88,4.60)	0.853
HIdec	S : 3v3	Bout1 − Bout2	−0.80	(-3.78,2.18)	0.804
47 / 1004 Bouts with missing measurements.		Bout1 − Bout3	1.60	(-1.38,4.58)	0.419
		Bout2 − Bout3	2.40	(-0.58,5.38)	0.142
	S : 5v5	Bout1 − Bout2	−0.10	(-2.21,2.01)	0.993
		Bout1 − Bout3	−1.10	(-3.21,1.01)	0.439
		Bout2 − Bout3	−1.00	(-3.11,1.11)	0.506
	S : 7v7	Bout1 − Bout2	−0.69	(-2.54,1.16)	0.654
		Bout1 − Bout3	−0.65	(-2.54,1.24)	0.700
		Bout2 − Bout3	0.04	(-1.84,1.93)	0.998
	M : 3v3	Bout1 − Bout2	0.17	(-2.56,2.89)	0.989
		Bout1 − Bout3	1.83	(-0.89,4.56)	0.254
		Bout2 − Bout3	1.67	(-1.06,4.39)	0.322
	M : 5v5	Bout1 − Bout2	—		
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	M : 7v7	Bout1 − Bout2	0.33	(-0.96,1.63)	0.817
		Bout1 − Bout3	0.15	(-1.15,1.46)	0.959
		Bout2 − Bout3	−0.18	(-1.48,1.11)	0.942
	L : 3v3	Bout1 − Bout2	−0.70	(-3.56,2.16)	0.833

U15	Pitch * No.	Comparison	Estimate	95% Adj. C.I.	Adj. *p*-value
		Bout1 − Bout3	0.30	(-2.56,3.16)	0.967
		Bout2 − Bout3	1.00	(-1.98,3.98)	0.711
	L : 5v5	Bout1 − Bout2	0.60	(-1.51,2.71)	0.782
		Bout1 − Bout3	0.60	(-1.51,2.71)	0.782
		Bout2 − Bout3	−0.00	(-2.11,2.11)	1.000
	L : 7v7	Bout1 − Bout2	0.36	(-1.43,2.14)	0.885
		Bout1 − Bout3	−0.14	(-1.93,1.64)	0.981
		Bout2 − Bout3	−0.50	(-2.28,1.28)	0.787
AL3D (AU)	S : 3v3	Bout1 − Bout2	0.07	(-1.17,1.30)	0.991
44 / 1004 Bouts with missing measurements.		Bout1 − Bout3	0.63	(-0.60,1.87)	0.452
		Bout2 − Bout3	0.57	(-0.67,1.80)	0.529
	S : 5v5	Bout1 − Bout2	−0.04	(-1.00,0.92)	0.995
		Bout1 − Bout3	−0.15	(-1.11,0.81)	0.928
		Bout2 − Bout3	−0.11	(-1.07,0.85)	0.961
	S : 7v7	Bout1 − Bout2	−0.27	(-1.11,0.57)	0.732
		Bout1 − Bout3	−0.16	(-1.00,0.68)	0.894
		Bout2 − Bout3	0.11	(-0.73,0.95)	0.951
	M : 3v3	Bout1 − Bout2	0.22	(-1.02,1.45)	0.911
		Bout1 − Bout3	1.08	(-0.15,2.32)	0.099
		Bout2 − Bout3	0.87	(-0.37,2.10)	0.227
	M : 5v5	Bout1 − Bout2	—		
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	M : 7v7	Bout1 − Bout2	0.38	(-0.20,0.95)	0.276
		Bout1 − Bout3	−0.30	(-0.88,0.28)	0.448
		Bout2 − Bout3	−0.68	(-1.25,-0.10)	0.017
	L : 3v3	Bout1 − Bout2	0.65	(-0.59,1.89)	0.433
		Bout1 − Bout3	1.37	(0.13,2.60)	0.026
		Bout2 − Bout3	0.72	(-0.52,1.95)	0.362
	L : 5v5	Bout1 − Bout2	0.25	(-0.71,1.21)	0.813
		Bout1 − Bout3	0.71	(-0.25,1.67)	0.191
		Bout2 − Bout3	0.46	(-0.50,1.42)	0.497
	L : 7v7	Bout1 − Bout2	0.16	(-0.64,0.97)	0.882
		Bout1 − Bout3	0.31	(-0.50,1.12)	0.646
		Bout2 − Bout3	0.14	(-0.67,0.95)	0.910
Impact (min^{-1})	S : 3v3	Bout1 − Bout2	0.05	(-0.06,0.16)	0.527
47 / 1004 Bouts with missing measurements.		Bout1 − Bout3	0.10	(-0.01,0.21)	0.079
		Bout2 − Bout3	0.05	(-0.06,0.16)	0.527
	S : 5v5	Bout1 − Bout2	−0.03	(-0.10,0.05)	0.726
		Bout1 − Bout3	−0.00	(-0.08,0.08)	1.000
		Bout2 − Bout3	0.02	(-0.05,0.10)	0.726
	S : 7v7	Bout1 − Bout2	−0.04	(-0.11,0.03)	0.374
		Bout1 − Bout3	0.00	(-0.07,0.07)	1.000
		Bout2 − Bout3	0.04	(-0.03,0.11)	0.389

U15	Pitch * No.	Comparison	Estimate	95% Adj. C.I.	Adj. *p*-value
	M : 3v3	Bout1 − Bout2	−0.04	(-0.14,0.06)	0.586
		Bout1 − Bout3	0.00	(-0.10,0.10)	1.000
		Bout2 − Bout3	0.04	(-0.06,0.14)	0.586
	M : 5v5	Bout1 − Bout2	—		
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	M : 7v7	Bout1 − Bout2	−0.02	(-0.07,0.03)	0.628
		Bout1 − Bout3	−0.03	(-0.08,0.02)	0.331
		Bout2 − Bout3	−0.01	(-0.06,0.04)	0.865
	L : 3v3	Bout1 − Bout2	−0.01	(-0.11,0.10)	0.981
		Bout1 − Bout3	0.04	(-0.06,0.15)	0.615
		Bout2 − Bout3	0.05	(-0.06,0.16)	0.527
	L : 5v5	Bout1 − Bout2	0.02	(-0.05,0.10)	0.726
		Bout1 − Bout3	0.02	(-0.05,0.10)	0.726
		Bout2 − Bout3	0.00	(-0.08,0.08)	1.000
	L : 7v7	Bout1 − Bout2	−0.04	(-0.10,0.03)	0.401
		Bout1 − Bout3	0.00	(-0.06,0.06)	1.000
		Bout2 − Bout3	0.04	(-0.03,0.10)	0.401
HIRD (m)	S : 3v3	Bout1 − Bout2	2.60	(-28.52,33.72)	0.979
101 / 1004 Bouts with missing measurements.		Bout1 − Bout3	17.60	(-13.52,48.72)	0.380
		Bout2 − Bout3	15.00	(-16.12,46.12)	0.495
	S : 5v5	Bout1 − Bout2	−4.20	(-26.20,17.80)	0.895
		Bout1 − Bout3	−4.30	(-26.30,17.70)	0.890
		Bout2 − Bout3	−0.10	(-22.10,21.90)	1.000
	S : 7v7	Bout1 − Bout2	8.54	(-10.76,27.84)	0.552
		Bout1 − Bout3	4.06	(-15.63,23.76)	0.879
		Bout2 − Bout3	−4.47	(-24.17,15.22)	0.855
	M : 3v3	Bout1 − Bout2	−3.17	(-31.57,25.24)	0.963
		Bout1 − Bout3	−0.00	(-28.40,28.40)	1.000
		Bout2 − Bout3	3.17	(-25.24,31.57)	0.963
	M : 5v5	Bout1 − Bout2	—		
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	M : 7v7	Bout1 − Bout2	−0.52	(-14.44,13.40)	0.996
		Bout1 − Bout3	−10.75	(-24.53,3.03)	0.160
		Bout2 − Bout3	−10.23	(-24.01,3.55)	0.190
	L : 3v3	Bout1 − Bout2	14.83	(-14.96,44.62)	0.472
		Bout1 − Bout3	1.83	(-27.96,31.62)	0.989
		Bout2 − Bout3	−13.00	(-44.12,18.12)	0.589
	L : 5v5	Bout1 − Bout2	8.80	(-13.20,30.80)	0.616
		Bout1 − Bout3	20.80	(-1.20,42.80)	0.068
		Bout2 − Bout3	12.00	(-10.00,34.00)	0.407
	L : 7v7	Bout1 − Bout2	2.38	(-16.91,21.68)	0.955
		Bout1 − Bout3	2.54	(-16.76,21.84)	0.949

U15	Pitch * No.	Comparison	Estimate	95% Adj. C.I.	Adj. *p*-value
		Bout2 − Bout3	0.15	(-19.14,19.45)	1.000
HSRD (m)	S : 3v3	Bout1 − Bout2	1.00	(-24.30,26.30)	0.995
101 / 1004 Bouts with missing measurements.		Bout1 − Bout3	12.20	(-13.10,37.50)	0.494
		Bout2 − Bout3	11.20	(-14.10,36.50)	0.552
	S : 5v5	Bout1 − Bout2	−3.10	(-20.99,14.79)	0.913
		Bout1 − Bout3	−1.60	(-19.49,16.29)	0.976
		Bout2 − Bout3	1.50	(-16.39,19.39)	0.979
	S : 7v7	Bout1 − Bout2	5.85	(-9.84,21.54)	0.656
		Bout1 − Bout3	4.05	(-11.96,20.06)	0.823
		Bout2 − Bout3	−1.79	(-17.81,14.22)	0.963
	M : 3v3	Bout1 − Bout2	−6.67	(-29.76,16.43)	0.777
		Bout1 − Bout3	−9.00	(-32.10,14.10)	0.631
		Bout2 − Bout3	−2.33	(-25.43,20.76)	0.969
	M : 5v5	Bout1 − Bout2	—		
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	M : 7v7	Bout1 − Bout2	−1.40	(-12.71,9.91)	0.955
		Bout1 − Bout3	−5.76	(-16.96,5.45)	0.450
		Bout2 − Bout3	−4.36	(-15.56,6.85)	0.632
	L : 3v3	Bout1 − Bout2	13.87	(-10.36,38.09)	0.371
		Bout1 − Bout3	3.47	(-20.76,27.69)	0.940
		Bout2 − Bout3	−10.40	(-35.70,14.90)	0.599
	L : 5v5	Bout1 − Bout2	−0.80	(-18.69,17.09)	0.994
		Bout1 − Bout3	10.10	(-7.79,27.99)	0.381
		Bout2 − Bout3	10.90	(-6.99,28.79)	0.326
	L : 7v7	Bout1 − Bout2	2.54	(-13.15,18.23)	0.924
		Bout1 − Bout3	1.62	(-14.07,17.31)	0.968
		Bout2 − Bout3	−0.92	(-16.61,14.77)	0.990
VHSRD (m)	S : 3v3	Bout1 − Bout2	0.60	(-11.81,13.01)	0.993
103 / 1004 Bouts with missing measurements.		Bout1 − Bout3	0.80	(-11.61,13.21)	0.987
		Bout2 − Bout3	0.20	(-12.21,12.61)	0.999
	S : 5v5	Bout1 − Bout2	0.00	(-9.02,9.02)	1.000
		Bout1 − Bout3	−0.10	(-9.12,8.92)	1.000
		Bout2 − Bout3	−0.10	(-8.88,8.68)	1.000
	S : 7v7	Bout1 − Bout2	1.00	(-6.70,8.70)	0.950
		Bout1 − Bout3	0.99	(-6.86,8.85)	0.953
		Bout2 − Bout3	−0.01	(-7.86,7.85)	1.000
	M : 3v3	Bout1 − Bout2	1.83	(-9.50,13.16)	0.924
		Bout1 − Bout3	−0.00	(-11.33,11.33)	1.000
		Bout2 − Bout3	−1.83	(-13.16,9.50)	0.924
	M : 5v5	Bout1 − Bout2	—		
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	M : 7v7	Bout1 − Bout2	−0.16	(-5.71,5.39)	0.997

U15	Pitch * No.	Comparison	Estimate	95% Adj. C.I.	Adj. *p*-value
		Bout1 − Bout3	0.34	(-5.16,5.83)	0.989
		Bout2 − Bout3	0.50	(-5.00,5.99)	0.975
	L : 3v3	Bout1 − Bout2	12.47	(0.58,24.35)	0.037
		Bout1 − Bout3	10.87	(-1.02,22.75)	0.081
		Bout2 − Bout3	−1.60	(-14.01,10.81)	0.951
	L : 5v5	Bout1 − Bout2	−2.20	(-10.98,6.58)	0.826
		Bout1 − Bout3	0.20	(-8.58,8.98)	0.998
		Bout2 − Bout3	2.40	(-6.38,11.18)	0.797
	L : 7v7	Bout1 − Bout2	−0.46	(-8.32,7.39)	0.990
		Bout1 − Bout3	0.15	(-7.70,8.01)	0.999
		Bout2 − Bout3	0.62	(-7.08,8.31)	0.981

U16	Pitch * No.	Comparison	Estimate	95% Adj. C.I.	Adj. *p*-value
TD (m)	S : 3v3	Bout1 − Bout2	15.50	(-107.70,138.70)	0.953
48 / 1004 Bouts with missing measurements.		Bout1 − Bout3	10.75	(-112.45,133.95)	0.977
		Bout2 − Bout3	−4.75	(-127.95,118.45)	0.995
	S : 5v5	Bout1 − Bout2	−47.00	(-293.40,199.40)	0.895
		Bout1 − Bout3	−5.00	(-251.40,241.40)	0.999
		Bout2 − Bout3	42.00	(-204.40,288.40)	0.916
	S : 7v7	Bout1 − Bout2	16.25	(-106.95,139.45)	0.949
		Bout1 − Bout3	34.50	(-88.70,157.70)	0.788
		Bout2 − Bout3	18.25	(-104.95,141.45)	0.936
	M : 3v3	Bout1 − Bout2	−1.07	(-85.73,83.59)	1.000
		Bout1 − Bout3	33.33	(-48.80,115.47)	0.607
		Bout2 − Bout3	34.40	(-50.26,119.06)	0.606
	M : 5v5	Bout1 − Bout2	8.00	(-238.40,254.40)	0.997
		Bout1 − Bout3	26.00	(-220.40,272.40)	0.967
		Bout2 − Bout3	18.00	(-228.40,264.40)	0.984
	M : 7v7	Bout1 − Bout2	26.00	(-97.20,149.20)	0.873
		Bout1 − Bout3	16.25	(-106.95,139.45)	0.949
		Bout2 − Bout3	−9.75	(-132.95,113.45)	0.981
	L : 3v3	Bout1 − Bout2	−12.14	(-105.27,80.99)	0.950
		Bout1 − Bout3	−12.86	(-105.99,80.27)	0.944
		Bout2 − Bout3	−0.71	(-93.85,92.42)	1.000
	L : 5v5	Bout1 − Bout2	—		
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	L : 7v7	Bout1 − Bout2	−4.20	(-114.39,105.99)	0.996
		Bout1 − Bout3	22.20	(-87.99,132.39)	0.884
		Bout2 − Bout3	26.40	(-83.79,136.59)	0.840
RD (m·min^{-1})	S : 3v3	Bout1 − Bout2	2.75	(-19.38,24.88)	0.954
47 / 1004 Bouts with missing measurements.		Bout1 − Bout3	1.75	(-20.38,23.88)	0.981
		Bout2 − Bout3	−1.00	(-23.13,21.13)	0.994
	S : 5v5	Bout1 − Bout2	−7.00	(-51.26,37.26)	0.927
		Bout1 − Bout3	−1.00	(-45.26,43.26)	0.998
		Bout2 − Bout3	6.00	(-38.26,50.26)	0.946
	S : 7v7	Bout1 − Bout2	4.00	(-18.13,26.13)	0.906
		Bout1 − Bout3	8.50	(-13.63,30.63)	0.639
		Bout2 − Bout3	4.50	(-17.63,26.63)	0.882
	M : 3v3	Bout1 − Bout2	−0.25	(-15.46,14.96)	0.999
		Bout1 − Bout3	8.33	(-6.42,23.09)	0.381
		Bout2 − Bout3	8.58	(-6.62,23.79)	0.382
	M : 5v5	Bout1 − Bout2	5.00	(-39.26,49.26)	0.962
		Bout1 − Bout3	6.00	(-38.26,50.26)	0.946
		Bout2 − Bout3	1.00	(-43.26,45.26)	0.998
	M : 7v7	Bout1 − Bout2	5.00	(-17.13,27.13)	0.856
		Bout1 − Bout3	2.75	(-19.38,24.88)	0.954
		Bout2 − Bout3	−2.25	(-24.38,19.88)	0.969

U16	Pitch * No.	Comparison	Estimate	95% Adj. C.I.	Adj. *p*-value
	L : 3v3	Bout1 − Bout2	−4.14	(-20.87,12.59)	0.830
		Bout1 − Bout3	−4.43	(-21.16,12.30)	0.808
		Bout2 − Bout3	−0.29	(-17.02,16.44)	0.999
	L : 5v5	Bout1 − Bout2	—		
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	L : 7v7	Bout1 − Bout2	−1.40	(-21.19,18.39)	0.985
		Bout1 − Bout3	6.40	(-13.39,26.19)	0.728
		Bout2 − Bout3	7.80	(-11.99,27.59)	0.625
V_{AVG} (km·h^{-1})	S : 3v3	Bout1 − Bout2	0.20	(-1.13,1.53)	0.934
47 / 1004 Bouts with missing measurements.		Bout1 − Bout3	0.12	(-1.21,1.46)	0.974
		Bout2 − Bout3	−0.08	(-1.41,1.26)	0.990
	S : 5v5	Bout1 − Bout2	−0.40	(-3.06,2.26)	0.934
		Bout1 − Bout3	−0.10	(-2.76,2.56)	0.996
		Bout2 − Bout3	0.30	(-2.36,2.96)	0.962
	S : 7v7	Bout1 − Bout2	0.25	(-1.08,1.58)	0.898
		Bout1 − Bout3	0.50	(-0.83,1.83)	0.652
		Bout2 − Bout3	0.25	(-1.08,1.58)	0.898
	M : 3v3	Bout1 − Bout2	−0.02	(-0.93,0.89)	0.998
		Bout1 − Bout3	0.49	(-0.40,1.38)	0.399
		Bout2 − Bout3	0.51	(-0.40,1.42)	0.390
	M : 5v5	Bout1 − Bout2	0.30	(-2.36,2.96)	0.962
		Bout1 − Bout3	0.40	(-2.26,3.06)	0.934
		Bout2 − Bout3	0.10	(-2.56,2.76)	0.996
	M : 7v7	Bout1 − Bout2	0.27	(-1.06,1.61)	0.878
		Bout1 − Bout3	0.15	(-1.18,1.48)	0.962
		Bout2 − Bout3	−0.13	(-1.46,1.21)	0.974
	L : 3v3	Bout1 − Bout2	−0.23	(-1.23,0.78)	0.855
		Bout1 − Bout3	−0.24	(-1.25,0.76)	0.838
		Bout2 − Bout3	−0.01	(-1.02,0.99)	0.999
	L : 5v5	Bout1 − Bout2	—		
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	L : 7v7	Bout1 − Bout2	−0.08	(-1.27,1.11)	0.986
		Bout1 − Bout3	0.38	(-0.81,1.57)	0.734
		Bout2 − Bout3	0.46	(-0.73,1.65)	0.636
V_{MAX} (km·h^{-1})	S : 3v3	Bout1 − Bout2	0.52	(-5.34,6.39)	0.976
47 / 1004 Bouts with missing measurements.		Bout1 − Bout3	−1.10	(-6.97,4.77)	0.899
		Bout2 − Bout3	−1.63	(-7.49,4.24)	0.792
	S : 5v5	Bout1 − Bout2	−3.80	(-15.53,7.93)	0.727
		Bout1 − Bout3	−2.60	(-14.33,9.13)	0.861
		Bout2 − Bout3	1.20	(-10.53,12.93)	0.969
	S : 7v7	Bout1 − Bout2	−0.85	(-6.72,5.02)	0.938
		Bout1 − Bout3	1.58	(-4.29,7.44)	0.803
		Bout2 − Bout3	2.42	(-3.44,8.29)	0.596

U16	Pitch * No.	Comparison	Estimate	95% Adj. C.I.	Adj. *p*-value
	M : 3v3	Bout1 − Bout2	−0.10	(-4.13,3.93)	0.998
		Bout1 − Bout3	2.88	(-1.03,6.79)	0.195
		Bout2 − Bout3	2.98	(-1.05,7.01)	0.192
	M : 5v5	Bout1 − Bout2	0.50	(-11.23,12.23)	0.994
		Bout1 − Bout3	0.40	(-11.33,12.13)	0.996
		Bout2 − Bout3	−0.10	(-11.83,11.63)	1.000
	M : 7v7	Bout1 − Bout2	2.15	(-3.72,8.02)	0.665
		Bout1 − Bout3	−0.57	(-6.44,5.29)	0.971
		Bout2 − Bout3	−2.73	(-8.59,3.14)	0.520
	L : 3v3	Bout1 − Bout2	0.00	(-4.43,4.43)	1.000
		Bout1 − Bout3	−0.21	(-4.65,4.22)	0.993
		Bout2 − Bout3	−0.21	(-4.65,4.22)	0.993
	L : 5v5	Bout1 − Bout2	—		
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	L : 7v7	Bout1 − Bout2	−2.62	(-7.87,2.63)	0.470
		Bout1 − Bout3	0.26	(-4.99,5.51)	0.993
		Bout2 − Bout3	2.88	(-2.37,8.13)	0.402
HRAVG (% HRMAX) *151 / 1004 Bouts with missing measurements.*	S : 3v3	Bout1 − Bout2	1.00	(-14.81,16.81)	0.988
		Bout1 − Bout3	3.70	(-12.11,19.51)	0.847
		Bout2 − Bout3	2.70	(-13.11,18.51)	0.915
	S : 5v5	Bout1 − Bout2	−6.40	(-28.76,15.96)	0.780
		Bout1 − Bout3	−2.40	(-24.76,19.96)	0.966
		Bout2 − Bout3	4.00	(-18.36,26.36)	0.907
	S : 7v7	Bout1 − Bout2	−3.57	(-16.48,9.34)	0.793
		Bout1 − Bout3	−0.17	(-13.08,12.74)	0.999
		Bout2 − Bout3	3.40	(-9.51,16.31)	0.810
	M : 3v3	Bout1 − Bout2	−2.50	(-10.18,5.19)	0.726
		Bout1 − Bout3	0.90	(-6.55,8.35)	0.957
		Bout2 − Bout3	3.40	(-4.29,11.08)	0.553
	M : 5v5	Bout1 − Bout2	−4.00	(-26.36,18.36)	0.907
		Bout1 − Bout3	−2.50	(-24.86,19.86)	0.963
		Bout2 − Bout3	1.50	(-20.86,23.86)	0.986
	M : 7v7	Bout1 − Bout2	−1.27	(-14.18,11.64)	0.971
		Bout1 − Bout3	−3.80	(-16.71,9.11)	0.769
		Bout2 − Bout3	−2.53	(-15.44,10.38)	0.890
	L : 3v3	Bout1 − Bout2	−3.38	(-12.51,5.75)	0.659
		Bout1 − Bout3	−3.68	(-12.81,5.45)	0.610
		Bout2 − Bout3	−0.30	(-9.43,8.83)	0.997
	L : 5v5	Bout1 − Bout2	—		
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	L : 7v7	Bout1 − Bout2	−5.93	(-17.11,5.26)	0.427
		Bout1 − Bout3	−2.90	(-14.08,8.28)	0.815
		Bout2 − Bout3	3.02	(-8.16,14.21)	0.801

U16	Pitch * No.	Comparison	Estimate	95% Adj. C.I.	Adj. *p*-value
HRMAX (%HRMAX)	S : 3v3	Bout1 − Bout2	2.35	(-12.52,17.22)	0.927
151 / 1004 Bouts with missing measurements.		Bout1 − Bout3	1.90	(-12.97,16.77)	0.952
		Bout2 − Bout3	−0.45	(-15.32,14.42)	0.997
	S : 5v5	Bout1 − Bout2	−2.50	(-23.53,18.53)	0.958
		Bout1 − Bout3	−2.50	(-23.53,18.53)	0.958
		Bout2 − Bout3	−0.00	(-21.03,21.03)	1.000
	S : 7v7	Bout1 − Bout2	−0.23	(-12.37,11.91)	0.999
		Bout1 − Bout3	4.30	(-7.84,16.44)	0.683
		Bout2 − Bout3	4.53	(-7.61,16.67)	0.655
	M : 3v3	Bout1 − Bout2	−1.98	(-9.21,5.24)	0.795
		Bout1 − Bout3	−0.03	(-7.04,6.98)	1.000
		Bout2 − Bout3	1.95	(-5.27,9.17)	0.802
	M : 5v5	Bout1 − Bout2	−1.50	(-22.53,19.53)	0.985
		Bout1 − Bout3	−4.00	(-25.03,17.03)	0.896
		Bout2 − Bout3	−2.50	(-23.53,18.53)	0.958
	M : 7v7	Bout1 − Bout2	1.77	(-10.37,13.91)	0.938
		Bout1 − Bout3	−2.60	(-14.74,9.54)	0.870
		Bout2 − Bout3	−4.37	(-16.51,7.77)	0.675
	L : 3v3	Bout1 − Bout2	−2.63	(-11.22,5.95)	0.751
		Bout1 − Bout3	−3.25	(-11.83,5.33)	0.647
		Bout2 − Bout3	−0.62	(-9.20,7.97)	0.984
	L : 5v5	Bout1 − Bout2	—		
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	L : 7v7	Bout1 − Bout2	−4.77	(-15.29,5.74)	0.535
		Bout1 − Bout3	−2.40	(-12.91,8.11)	0.854
		Bout2 − Bout3	2.37	(-8.14,12.89)	0.856
RPE (6-20)	S : 3v3	Bout1 − Bout2	−1.25	(-4.42,1.92)	0.624
2 / 1004 Bouts with missing measurements.		Bout1 − Bout3	−3.00	(-6.17,0.17)	0.068
		Bout2 − Bout3	−1.75	(-4.92,1.42)	0.397
	S : 5v5	Bout1 − Bout2	1.00	(-5.33,7.33)	0.927
		Bout1 − Bout3	−1.00	(-7.33,5.33)	0.927
		Bout2 − Bout3	−2.00	(-8.33,4.33)	0.739
	S : 7v7	Bout1 − Bout2	−0.50	(-3.67,2.67)	0.927
		Bout1 − Bout3	−1.75	(-4.92,1.42)	0.397
		Bout2 − Bout3	−1.25	(-4.42,1.92)	0.624
	M : 3v3	Bout1 − Bout2	−1.60	(-3.77,0.58)	0.197
		Bout1 − Bout3	−1.78	(-3.89,0.33)	0.119
		Bout2 − Bout3	−0.18	(-2.36,2.00)	0.979
	M : 5v5	Bout1 − Bout2	−1.00	(-5.48,3.48)	0.860
		Bout1 − Bout3	−4.50	(-8.98,-0.02)	0.049
		Bout2 − Bout3	−3.50	(-7.98,0.98)	0.159
	M : 7v7	Bout1 − Bout2	−1.75	(-4.92,1.42)	0.397
		Bout1 − Bout3	−4.75	(-7.92,-1.58)	0.001
		Bout2 − Bout3	−3.00	(-6.17,0.17)	0.068

U16	Pitch * No.	Comparison	Estimate	95% Adj. C.I.	Adj. *p*-value
	L : 3v3	Bout1 − Bout2	−2.43	(-4.82,-0.03)	0.046
		Bout1 − Bout3	−2.14	(-4.54,0.25)	0.090
		Bout2 − Bout3	0.29	(-2.11,2.68)	0.958
	L : 5v5	Bout1 − Bout2	—		
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	L : 7v7	Bout1 − Bout2	−1.80	(-4.63,1.03)	0.295
		Bout1 − Bout3	−1.60	(-4.43,1.23)	0.381
		Bout2 − Bout3	0.20	(-2.63,3.03)	0.985
Sprint·min^{-1}	S : 3v3	Bout1 − Bout2	−0.00	(-1.84,1.84)	1.000
47 / 1004 Bouts with missing measurements.		Bout1 − Bout3	0.19	(-1.65,2.03)	0.969
		Bout2 − Bout3	0.19	(-1.65,2.03)	0.969
	S : 5v5	Bout1 − Bout2	−1.00	(-4.68,2.68)	0.800
		Bout1 − Bout3	−0.25	(-3.93,3.43)	0.986
		Bout2 − Bout3	0.75	(-2.93,4.43)	0.882
	S : 7v7	Bout1 − Bout2	0.13	(-1.72,1.97)	0.986
		Bout1 − Bout3	0.37	(-1.47,2.22)	0.882
		Bout2 − Bout3	0.25	(-1.59,2.09)	0.946
	M : 3v3	Bout1 − Bout2	0.06	(-1.21,1.32)	0.994
		Bout1 − Bout3	−0.19	(-1.42,1.03)	0.927
		Bout2 − Bout3	−0.25	(-1.52,1.02)	0.888
	M : 5v5	Bout1 − Bout2	0.75	(-2.93,4.43)	0.882
		Bout1 − Bout3	0.75	(-2.93,4.43)	0.882
		Bout2 − Bout3	−0.00	(-3.68,3.68)	1.000
	M : 7v7	Bout1 − Bout2	0.87	(-0.97,2.72)	0.505
		Bout1 − Bout3	0.50	(-1.34,2.34)	0.800
		Bout2 − Bout3	−0.38	(-2.22,1.47)	0.882
	L : 3v3	Bout1 − Bout2	0.00	(-1.39,1.39)	1.000
		Bout1 − Bout3	0.25	(-1.14,1.64)	0.907
		Bout2 − Bout3	0.25	(-1.14,1.64)	0.907
	L : 5v5	Bout1 − Bout2	—		
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	L : 7v7	Bout1 − Bout2	0.10	(-1.55,1.75)	0.989
		Bout1 − Bout3	0.45	(-1.20,2.10)	0.797
		Bout2 − Bout3	0.35	(-1.30,2.00)	0.872
HIacc	S : 3v3	Bout1 − Bout2	−0.50	(-7.50,6.50)	0.985
47 / 1004 Bouts with missing measurements.		Bout1 − Bout3	2.50	(-4.50,9.50)	0.679
		Bout2 − Bout3	3.00	(-4.00,10.00)	0.573
	S : 5v5	Bout1 − Bout2	−3.00	(-16.99,10.99)	0.870
		Bout1 − Bout3	−2.00	(-15.99,11.99)	0.940
		Bout2 − Bout3	1.00	(-12.99,14.99)	0.985
	S : 7v7	Bout1 − Bout2	−0.75	(-7.75,6.25)	0.966
		Bout1 − Bout3	2.75	(-4.25,9.75)	0.626
		Bout2 − Bout3	3.50	(-3.50,10.50)	0.469

U16	Pitch * No.	Comparison	Estimate	95% Adj. C.I.	Adj. *p*-value
	M : 3v3	Bout1 − Bout2	−0.25	(-5.06,4.56)	0.992
		Bout1 − Bout3	0.00	(-4.66,4.66)	1.000
		Bout2 − Bout3	0.25	(-4.56,5.06)	0.992
	M : 5v5	Bout1 − Bout2	−6.00	(-19.99,7.99)	0.573
		Bout1 − Bout3	3.00	(-10.99,16.99)	0.870
		Bout2 − Bout3	9.00	(-4.99,22.99)	0.287
	M : 7v7	Bout1 − Bout2	−0.00	(-7.00,7.00)	1.000
		Bout1 − Bout3	1.00	(-6.00,8.00)	0.940
		Bout2 − Bout3	1.00	(-6.00,8.00)	0.940
	L : 3v3	Bout1 − Bout2	−0.86	(-6.15,4.43)	0.923
		Bout1 − Bout3	2.14	(-3.15,7.43)	0.608
		Bout2 − Bout3	3.00	(-2.29,8.29)	0.378
	L : 5v5	Bout1 − Bout2	—		
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	L : 7v7	Bout1 − Bout2	1.20	(-5.06,7.46)	0.894
		Bout1 − Bout3	3.00	(-3.26,9.26)	0.499
		Bout2 − Bout3	1.80	(-4.46,8.06)	0.778
HIdec	S : 3v3	Bout1 − Bout2	−0.00	(-3.33,3.33)	1.000
47 / 1004 Bouts with missing measurements.		Bout1 − Bout3	0.50	(-2.83,3.83)	0.934
		Bout2 − Bout3	0.50	(-2.83,3.83)	0.934
	S : 5v5	Bout1 − Bout2	−3.00	(-9.67,3.67)	0.542
		Bout1 − Bout3	1.00	(-5.67,7.67)	0.934
		Bout2 − Bout3	4.00	(-2.67,10.67)	0.337
	S : 7v7	Bout1 − Bout2	1.00	(-2.33,4.33)	0.761
		Bout1 − Bout3	1.00	(-2.33,4.33)	0.761
		Bout2 − Bout3	−0.00	(-3.33,3.33)	1.000
	M : 3v3	Bout1 − Bout2	−0.65	(-2.94,1.64)	0.782
		Bout1 − Bout3	1.00	(-1.22,3.22)	0.542
		Bout2 − Bout3	1.65	(-0.64,3.94)	0.208
	M : 5v5	Bout1 − Bout2	0.00	(-6.67,6.67)	1.000
		Bout1 − Bout3	2.00	(-4.67,8.67)	0.761
		Bout2 − Bout3	2.00	(-4.67,8.67)	0.761
	M : 7v7	Bout1 − Bout2	1.50	(-1.83,4.83)	0.542
		Bout1 − Bout3	0.50	(-2.83,3.83)	0.934
		Bout2 − Bout3	−1.00	(-4.33,2.33)	0.761
	L : 3v3	Bout1 − Bout2	0.14	(-2.38,2.66)	0.990
		Bout1 − Bout3	0.14	(-2.38,2.66)	0.990
		Bout2 − Bout3	−0.00	(-2.52,2.52)	1.000
	L : 5v5	Bout1 − Bout2	—		
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	L : 7v7	Bout1 − Bout2	−1.00	(-3.98,1.98)	0.711
		Bout1 − Bout3	−0.80	(-3.78,2.18)	0.804
		Bout2 − Bout3	0.20	(-2.78,3.18)	0.986

U16	Pitch * No.	Comparison	Estimate	95% Adj. C.I.	Adj. *p*-value
AL_{3D} (AU)	S : 3v3	Bout1 − Bout2	0.42	(-1.09,1.94)	0.787
44 / 1004 Bouts with missing measurements.		Bout1 − Bout3	0.25	(-1.26,1.76)	0.921
		Bout2 − Bout3	−0.18	(-1.69,1.34)	0.960
	S : 5v5	Bout1 − Bout2	−0.60	(-3.63,2.43)	0.888
		Bout1 − Bout3	−0.40	(-3.43,2.63)	0.948
		Bout2 − Bout3	0.20	(-2.83,3.23)	0.987
	S : 7v7	Bout1 − Bout2	0.20	(-1.31,1.71)	0.948
		Bout1 − Bout3	0.83	(-0.69,2.34)	0.407
		Bout2 − Bout3	0.63	(-0.89,2.14)	0.597
	M : 3v3	Bout1 − Bout2	0.20	(-0.84,1.24)	0.891
		Bout1 − Bout3	0.91	(-0.10,1.92)	0.087
		Bout2 − Bout3	0.71	(-0.33,1.75)	0.247
	M : 5v5	Bout1 − Bout2	0.70	(-2.33,3.73)	0.850
		Bout1 − Bout3	0.40	(-2.63,3.43)	0.948
		Bout2 − Bout3	−0.30	(-3.33,2.73)	0.971
	M : 7v7	Bout1 − Bout2	0.38	(-1.14,1.89)	0.830
		Bout1 − Bout3	0.40	(-1.11,1.91)	0.809
		Bout2 − Bout3	0.02	(-1.49,1.54)	0.999
	L : 3v3	Bout1 − Bout2	−0.30	(-1.44,0.84)	0.812
		Bout1 − Bout3	−0.07	(-1.22,1.07)	0.988
		Bout2 − Bout3	0.23	(-0.92,1.37)	0.886
	L : 5v5	Bout1 − Bout2	—		
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	L : 7v7	Bout1 − Bout2	−0.18	(-1.53,1.17)	0.948
		Bout1 − Bout3	0.38	(-0.97,1.73)	0.787
		Bout2 − Bout3	0.56	(-0.79,1.91)	0.596
Impact (min^{-1})	S : 3v3	Bout1 − Bout2	−0.00	(-0.12,0.12)	1.000
47 / 1004 Bouts with missing measurements.		Bout1 − Bout3	−0.06	(-0.18,0.06)	0.449
		Bout2 − Bout3	−0.06	(-0.18,0.06)	0.449
	S : 5v5	Bout1 − Bout2	0.00	(-0.24,0.24)	1.000
		Bout1 − Bout3	0.00	(-0.24,0.24)	1.000
		Bout2 − Bout3	0.00	(-0.24,0.24)	1.000
	S : 7v7	Bout1 − Bout2	−0.00	(-0.12,0.12)	1.000
		Bout1 − Bout3	0.13	(0.00,0.25)	0.042
		Bout2 − Bout3	0.13	(0.00,0.25)	0.042
	M : 3v3	Bout1 − Bout2	−0.03	(-0.12,0.05)	0.592
		Bout1 − Bout3	0.03	(-0.05,0.11)	0.700
		Bout2 − Bout3	0.06	(-0.02,0.15)	0.185
	M : 5v5	Bout1 − Bout2	−0.00	(-0.24,0.24)	1.000
		Bout1 − Bout3	−0.25	(-0.49,-0.01)	0.042
		Bout2 − Bout3	−0.25	(-0.49,-0.01)	0.042
	M : 7v7	Bout1 − Bout2	0.12	(0.00,0.25)	0.042
		Bout1 − Bout3	0.12	(0.00,0.25)	0.042
		Bout2 − Bout3	0.00	(-0.12,0.12)	1.000

U16	Pitch * No.	Comparison	Estimate	95% Adj. C.I.	Adj. *p*-value
	L : 3v3	Bout1 − Bout2	−0.00	(-0.09,0.09)	1.000
		Bout1 − Bout3	0.04	(-0.06,0.13)	0.633
		Bout2 − Bout3	0.04	(-0.06,0.13)	0.633
	L : 5v5	Bout1 − Bout2	—		
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	L : 7v7	Bout1 − Bout2	−0.05	(-0.16,0.06)	0.527
		Bout1 − Bout3	0.00	(-0.11,0.11)	1.000
		Bout2 − Bout3	0.05	(-0.06,0.16)	0.527
HIRD (m)	S : 3v3	Bout1 − Bout2	14.00	(-35.20,63.20)	0.782
101 / 1004 Bouts with missing measurements.		Bout1 − Bout3	−17.00	(-66.20,32.20)	0.696
		Bout2 − Bout3	−31.00	(-80.20,18.20)	0.301
	S : 5v5	Bout1 − Bout2	−20.00	(-89.58,49.58)	0.778
		Bout1 − Bout3	−16.00	(-85.58,53.58)	0.852
		Bout2 − Bout3	4.00	(-65.58,73.58)	0.990
	S : 7v7	Bout1 − Bout2	−1.33	(-41.50,38.84)	0.997
		Bout1 − Bout3	2.67	(-37.50,42.84)	0.987
		Bout2 − Bout3	4.00	(-36.17,44.17)	0.970
	M : 3v3	Bout1 − Bout2	−8.89	(-32.79,15.02)	0.657
		Bout1 − Bout3	32.78	(9.59,55.97)	0.003
		Bout2 − Bout3	41.67	(17.76,65.57)	<0.001
	M : 5v5	Bout1 − Bout2	−1.00	(-70.58,68.58)	0.999
		Bout1 − Bout3	−1.00	(-70.58,68.58)	0.999
		Bout2 − Bout3	−0.00	(-69.58,69.58)	1.000
	M : 7v7	Bout1 − Bout2	6.67	(-33.50,46.84)	0.920
		Bout1 − Bout3	−5.00	(-45.17,35.17)	0.954
		Bout2 − Bout3	−11.67	(-51.84,28.50)	0.774
	L : 3v3	Bout1 − Bout2	−15.83	(-44.24,12.57)	0.391
		Bout1 − Bout3	−20.00	(-48.40,8.40)	0.224
		Bout2 − Bout3	−4.17	(-32.57,24.24)	0.937
	L : 5v5	Bout1 − Bout2	—		
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	L : 7v7	Bout1 − Bout2	−8.00	(-42.79,26.79)	0.852
		Bout1 − Bout3	−6.25	(-41.04,28.54)	0.907
		Bout2 − Bout3	1.75	(-33.04,36.54)	0.992
HSRD (m)	S : 3v3	Bout1 − Bout2	8.50	(-31.50,48.50)	0.872
101 / 1004 Bouts with missing measurements.		Bout1 − Bout3	−9.00	(-49.00,31.00)	0.857
		Bout2 − Bout3	−17.50	(-57.50,22.50)	0.560
	S : 5v5	Bout1 − Bout2	−2.00	(-58.57,54.57)	0.996
		Bout1 − Bout3	−3.00	(-59.57,53.57)	0.991
		Bout2 − Bout3	−1.00	(-57.57,55.57)	0.999
	S : 7v7	Bout1 − Bout2	0.33	(-32.33,32.99)	1.000
		Bout1 − Bout3	0.33	(-32.33,32.99)	1.000
		Bout2 − Bout3	−0.00	(-32.66,32.66)	1.000

U16	Pitch * No.	Comparison	Estimate	95% Adj. C.I.	Adj. *p*-value
	M : 3v3	Bout1 − Bout2	−6.47	(-25.91,12.97)	0.714
		Bout1 − Bout3	23.00	(4.14,41.86)	0.012
		Bout2 − Bout3	29.47	(10.03,48.91)	0.001
	M : 5v5	Bout1 − Bout2	1.00	(-55.57,57.57)	0.999
		Bout1 − Bout3	1.00	(-55.57,57.57)	0.999
		Bout2 − Bout3	0.00	(-56.57,56.57)	1.000
	M : 7v7	Bout1 − Bout2	3.67	(-28.99,36.33)	0.962
		Bout1 − Bout3	−2.00	(-34.66,30.66)	0.989
		Bout2 − Bout3	−5.67	(-38.33,26.99)	0.913
	L : 3v3	Bout1 − Bout2	−0.50	(-23.60,22.60)	0.999
		Bout1 − Bout3	−11.17	(-34.26,11.93)	0.493
		Bout2 − Bout3	−10.67	(-33.76,12.43)	0.524
	L : 5v5	Bout1 − Bout2	—		
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	L : 7v7	Bout1 − Bout2	−3.50	(-31.79,24.79)	0.955
		Bout1 − Bout3	−1.50	(-29.79,26.79)	0.991
		Bout2 − Bout3	2.00	(-26.29,30.29)	0.985
VHSRD (m)	S : 3v3	Bout1 − Bout2	−0.00	(-19.62,19.62)	1.000
103 / 1004 Bouts with missing measurements.		Bout1 − Bout3	−0.50	(-20.12,19.12)	0.998
		Bout2 − Bout3	−0.50	(-20.12,19.12)	0.998
	S : 5v5	Bout1 − Bout2	−0.00	(-27.75,27.75)	1.000
		Bout1 − Bout3	0.00	(-27.75,27.75)	1.000
		Bout2 − Bout3	0.00	(-27.75,27.75)	1.000
	S : 7v7	Bout1 − Bout2	−0.00	(-16.02,16.02)	1.000
		Bout1 − Bout3	0.00	(-16.02,16.02)	1.000
		Bout2 − Bout3	0.00	(-16.02,16.02)	1.000
	M : 3v3	Bout1 − Bout2	0.53	(-9.01,10.06)	0.991
		Bout1 − Bout3	4.67	(-4.58,13.92)	0.463
		Bout2 − Bout3	4.14	(-5.40,13.67)	0.565
	M : 5v5	Bout1 − Bout2	0.00	(-27.75,27.75)	1.000
		Bout1 − Bout3	0.00	(-27.75,27.75)	1.000
		Bout2 − Bout3	−0.00	(-27.75,27.75)	1.000
	M : 7v7	Bout1 − Bout2	2.67	(-13.36,18.69)	0.919
		Bout1 − Bout3	3.00	(-13.02,19.02)	0.899
		Bout2 − Bout3	0.33	(-15.69,16.36)	0.999
	L : 3v3	Bout1 − Bout2	4.33	(-7.00,15.66)	0.642
		Bout1 − Bout3	0.67	(-10.66,12.00)	0.990
		Bout2 − Bout3	−3.67	(-15.00,7.66)	0.728
	L : 5v5	Bout1 − Bout2	—		
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	L : 7v7	Bout1 − Bout2	−1.75	(-15.63,12.13)	0.953
		Bout1 − Bout3	−0.25	(-14.13,13.63)	0.999
		Bout2 − Bout3	1.50	(-12.38,15.38)	0.965

U18	Pitch * No.	Comparison	Estimate	95% Adj. C.I.	Adj. *p*-value
TD (m)	S : 3v3	Bout1 − Bout2	0.56	(-48.72,49.84)	1.000
48 / 1004 Bouts with missing measurements.		Bout1 − Bout3	22.76	(-26.52,72.04)	0.524
		Bout2 − Bout3	22.20	(-27.08,71.48)	0.541
	S : 5v5	Bout1 − Bout2	−53.00	(-146.13,40.13)	0.376
		Bout1 − Bout3	−19.86	(-112.99,73.27)	0.871
		Bout2 − Bout3	33.14	(-59.99,126.27)	0.681
	S : 7v7	Bout1 − Bout2	19.40	(-58.52,97.32)	0.828
		Bout1 − Bout3	−7.20	(-85.12,70.72)	0.974
		Bout2 − Bout3	−26.60	(-104.52,51.32)	0.702
	M : 3v3	Bout1 − Bout2	5.14	(-57.48,67.76)	0.980
		Bout1 − Bout3	25.40	(-38.22,89.02)	0.617
		Bout2 − Bout3	20.26	(-42.36,82.88)	0.728
	M : 5v5	Bout1 − Bout2	8.00	(-92.59,108.59)	0.981
		Bout1 − Bout3	−7.83	(-108.43,92.76)	0.982
		Bout2 − Bout3	−15.83	(-116.43,84.76)	0.928
	M : 7v7	Bout1 − Bout2	8.70	(-69.22,86.62)	0.963
		Bout1 − Bout3	43.70	(-34.22,121.62)	0.386
		Bout2 − Bout3	35.00	(-42.92,112.92)	0.543
	L : 3v3	Bout1 − Bout2	40.58	(-20.10,101.27)	0.259
		Bout1 − Bout3	13.31	(-48.41,75.03)	0.868
		Bout2 − Bout3	−27.27	(-89.89,35.35)	0.563
	L : 5v5	Bout1 − Bout2	18.79	(-37.74,75.32)	0.715
		Bout1 − Bout3	31.21	(-25.32,87.74)	0.398
		Bout2 − Bout3	12.42	(-44.11,68.95)	0.864
	L : 7v7	Bout1 − Bout2	41.74	(-14.79,98.27)	0.193
		Bout1 − Bout3	41.33	(-15.98,98.64)	0.208
		Bout2 − Bout3	−0.41	(-57.71,56.90)	1.000
RD (m·min^{-1})	S : 3v3	Bout1 − Bout2	0.40	(-8.45,9.25)	0.994
47 / 1004 Bouts with missing measurements.		Bout1 − Bout3	4.92	(-3.93,13.77)	0.393
		Bout2 − Bout3	4.52	(-4.33,13.37)	0.454
	S : 5v5	Bout1 − Bout2	−9.71	(-26.44,7.02)	0.361
		Bout1 − Bout3	−4.86	(-21.59,11.87)	0.774
		Bout2 − Bout3	4.86	(-11.87,21.59)	0.774
	S : 7v7	Bout1 − Bout2	4.90	(-9.10,18.90)	0.690
		Bout1 − Bout3	−1.80	(-15.80,12.20)	0.951
		Bout2 − Bout3	−6.70	(-20.70,7.30)	0.500
	M : 3v3	Bout1 − Bout2	1.05	(-10.20,12.30)	0.974
		Bout1 − Bout3	6.33	(-5.10,17.76)	0.395
		Bout2 − Bout3	5.28	(-5.97,16.53)	0.513
	M : 5v5	Bout1 − Bout2	4.50	(-13.57,22.57)	0.828
		Bout1 − Bout3	−2.17	(-20.24,15.90)	0.957
		Bout2 − Bout3	−6.67	(-24.74,11.40)	0.662
	M : 7v7	Bout1 − Bout2	0.70	(-13.30,14.70)	0.992
		Bout1 − Bout3	9.30	(-4.70,23.30)	0.264

U18	Pitch * No.	Comparison	Estimate	95% Adj. C.I.	Adj. *p*-value
		Bout2 − Bout3	8.60	(-5.40,22.60)	0.320
	L : 3v3	Bout1 − Bout2	8.75	(-2.15,19.65)	0.144
		Bout1 − Bout3	2.00	(-9.09,13.09)	0.906
		Bout2 − Bout3	−6.75	(-18.00,4.50)	0.337
	L : 5v5	Bout1 − Bout2	4.79	(-5.36,14.94)	0.510
		Bout1 − Bout3	6.84	(-3.31,17.00)	0.254
		Bout2 − Bout3	2.05	(-8.10,12.21)	0.883
	L : 7v7	Bout1 − Bout2	10.53	(0.37,20.68)	0.040
		Bout1 − Bout3	10.38	(0.08,20.67)	0.048
		Bout2 − Bout3	−0.15	(-10.44,10.15)	0.999
V_{AVG} (km·h^{-1})	S : 3v3	Bout1 − Bout2	0.00	(-0.53,0.53)	1.000
47 / 1004 Bouts with missing measurements.		Bout1 − Bout3	0.28	(-0.25,0.82)	0.422
		Bout2 − Bout3	0.28	(-0.25,0.82)	0.422
	S : 5v5	Bout1 − Bout2	−0.59	(-1.59,0.42)	0.359
		Bout1 − Bout3	−0.31	(-1.32,0.69)	0.743
		Bout2 − Bout3	0.27	(-0.73,1.28)	0.802
	S : 7v7	Bout1 − Bout2	0.29	(-0.55,1.13)	0.697
		Bout1 − Bout3	−0.13	(-0.97,0.71)	0.930
		Bout2 − Bout3	−0.42	(-1.26,0.42)	0.470
	M : 3v3	Bout1 − Bout2	0.09	(-0.59,0.76)	0.949
		Bout1 − Bout3	0.39	(-0.30,1.07)	0.384
		Bout2 − Bout3	0.30	(-0.38,0.97)	0.554
	M : 5v5	Bout1 − Bout2	0.28	(-0.80,1.37)	0.813
		Bout1 − Bout3	−0.12	(-1.20,0.97)	0.966
		Bout2 − Bout3	−0.40	(-1.49,0.69)	0.663
	M : 7v7	Bout1 − Bout2	0.02	(-0.82,0.86)	0.998
		Bout1 − Bout3	0.57	(-0.27,1.41)	0.250
		Bout2 − Bout3	0.55	(-0.29,1.39)	0.275
	L : 3v3	Bout1 − Bout2	0.52	(-0.13,1.18)	0.145
		Bout1 − Bout3	0.11	(-0.56,0.77)	0.925
		Bout2 − Bout3	−0.42	(-1.09,0.26)	0.315
	L : 5v5	Bout1 − Bout2	0.29	(-0.32,0.90)	0.506
		Bout1 − Bout3	0.42	(-0.19,1.03)	0.246
		Bout2 − Bout3	0.13	(-0.48,0.74)	0.878
	L : 7v7	Bout1 − Bout2	0.64	(0.03,1.25)	0.036
		Bout1 − Bout3	0.63	(0.01,1.25)	0.045
		Bout2 − Bout3	−0.01	(-0.63,0.61)	0.999
V_{MAX} (km·h^{-1})	S : 3v3	Bout1 − Bout2	−1.09	(-3.43,1.26)	0.521
47 / 1004 Bouts with missing measurements.		Bout1 − Bout3	−0.33	(-2.67,2.02)	0.942
		Bout2 − Bout3	0.76	(-1.59,3.11)	0.727
	S : 5v5	Bout1 − Bout2	0.46	(-3.98,4.89)	0.968
		Bout1 − Bout3	−0.23	(-4.66,4.21)	0.992
		Bout2 − Bout3	−0.69	(-5.12,3.75)	0.930
	S : 7v7	Bout1 − Bout2	0.06	(-3.65,3.77)	0.999
		Bout1 − Bout3	−0.29	(-4.00,3.42)	0.982

U18	Pitch * No.	Comparison	Estimate	95% Adj. C.I.	Adj. *p*-value
		Bout2 − Bout3	−0.35	(-4.06,3.36)	0.973
	M : 3v3	Bout1 − Bout2	−0.59	(-3.57,2.39)	0.889
		Bout1 − Bout3	0.02	(-3.01,3.05)	1.000
		Bout2 − Bout3	0.61	(-2.37,3.59)	0.882
	M : 5v5	Bout1 − Bout2	0.33	(-4.46,5.12)	0.985
		Bout1 − Bout3	0.88	(-3.91,5.67)	0.902
		Bout2 − Bout3	0.55	(-4.24,5.34)	0.961
	M : 7v7	Bout1 − Bout2	−2.65	(-6.36,1.06)	0.215
		Bout1 − Bout3	−0.55	(-4.26,3.16)	0.935
		Bout2 − Bout3	2.10	(-1.61,5.81)	0.379
	L : 3v3	Bout1 − Bout2	0.31	(-2.58,3.20)	0.966
		Bout1 − Bout3	0.06	(-2.88,3.00)	0.999
		Bout2 − Bout3	−0.24	(-3.23,2.74)	0.980
	L : 5v5	Bout1 − Bout2	0.29	(-2.40,2.99)	0.964
		Bout1 − Bout3	−1.93	(-4.62,0.77)	0.213
		Bout2 − Bout3	−2.22	(-4.91,0.47)	0.129
	L : 7v7	Bout1 − Bout2	1.56	(-1.13,4.25)	0.363
		Bout1 − Bout3	1.67	(-1.05,4.40)	0.321
		Bout2 − Bout3	0.12	(-2.61,2.84)	0.994
HR$_{AVG}$ (% HR$_{MAX}$)	S : 3v3	Bout1 − Bout2	−4.01	(-8.63,0.60)	0.103
151 / 1004 Bouts with missing measurements.		Bout1 − Bout3	−2.76	(-7.38,1.85)	0.338
		Bout2 − Bout3	1.25	(-3.31,5.81)	0.796
	S : 5v5	Bout1 − Bout2	−3.77	(-12.22,4.68)	0.547
		Bout1 − Bout3	−0.64	(-9.09,7.81)	0.983
		Bout2 − Bout3	3.13	(-5.32,11.58)	0.660
	S : 7v7	Bout1 − Bout2	−3.89	(-10.96,3.18)	0.400
		Bout1 − Bout3	−5.66	(-12.73,1.41)	0.145
		Bout2 − Bout3	−1.77	(-8.84,5.30)	0.827
	M : 3v3	Bout1 − Bout2	−2.12	(-7.80,3.56)	0.655
		Bout1 − Bout3	0.75	(-5.03,6.52)	0.950
		Bout2 − Bout3	2.87	(-2.81,8.55)	0.462
	M : 5v5	Bout1 − Bout2	0.82	(-9.18,10.82)	0.980
		Bout1 − Bout3	1.89	(-7.68,11.46)	0.888
		Bout2 − Bout3	1.07	(-8.50,10.64)	0.963
	M : 7v7	Bout1 − Bout2	−2.43	(-9.50,4.64)	0.699
		Bout1 − Bout3	−2.24	(-9.31,4.83)	0.737
		Bout2 − Bout3	0.19	(-6.88,7.26)	0.998
	L : 3v3	Bout1 − Bout2	−1.42	(-7.10,4.26)	0.827
		Bout1 − Bout3	−3.24	(-8.92,2.45)	0.375
		Bout2 − Bout3	−1.81	(-7.59,3.96)	0.741
	L : 5v5	Bout1 − Bout2	−4.63	(-10.16,0.90)	0.121
		Bout1 − Bout3	−5.19	(-10.72,0.34)	0.071
		Bout2 − Bout3	−0.56	(-5.83,4.71)	0.966
	L : 7v7	Bout1 − Bout2	−4.69	(-9.82,0.44)	0.081
		Bout1 − Bout3	−4.81	(-10.01,0.39)	0.077

U18	Pitch * No.	Comparison	Estimate	95% Adj. C.I.	Adj. *p*-value
		Bout2 − Bout3	−0.12	(-5.32,5.08)	0.998
HRMAX (%HRMAX) *151 / 1004 Bouts with missing measurements.*	S : 3v3	Bout1 − Bout2	−3.13	(-7.46,1.21)	0.209
		Bout1 − Bout3	−2.46	(-6.80,1.88)	0.377
		Bout2 − Bout3	0.66	(-3.63,4.95)	0.930
	S : 5v5	Bout1 − Bout2	−0.76	(-8.70,7.19)	0.973
		Bout1 − Bout3	1.70	(-6.25,9.65)	0.870
		Bout2 − Bout3	2.46	(-5.49,10.40)	0.748
	S : 7v7	Bout1 − Bout2	−2.61	(-9.26,4.04)	0.627
		Bout1 − Bout3	−4.29	(-10.94,2.36)	0.284
		Bout2 − Bout3	−1.68	(-8.33,4.97)	0.824
	M : 3v3	Bout1 − Bout2	−1.42	(-6.77,3.92)	0.806
		Bout1 − Bout3	−0.35	(-5.78,5.08)	0.987
		Bout2 − Bout3	1.07	(-4.27,6.41)	0.885
	M : 5v5	Bout1 − Bout2	1.16	(-8.24,10.56)	0.955
		Bout1 − Bout3	1.66	(-7.34,10.67)	0.901
		Bout2 − Bout3	0.50	(-8.50,9.51)	0.991
	M : 7v7	Bout1 − Bout2	−0.71	(-7.36,5.94)	0.966
		Bout1 − Bout3	−0.06	(-6.71,6.59)	1.000
		Bout2 − Bout3	0.65	(-6.00,7.30)	0.971
	L : 3v3	Bout1 − Bout2	−0.69	(-6.04,4.65)	0.950
		Bout1 − Bout3	−1.17	(-6.52,4.17)	0.864
		Bout2 − Bout3	−0.48	(-5.91,4.95)	0.977
	L : 5v5	Bout1 − Bout2	−3.37	(-8.57,1.82)	0.280
		Bout1 − Bout3	−5.10	(-10.30,0.10)	0.056
		Bout2 − Bout3	−1.73	(-6.68,3.23)	0.692
	L : 7v7	Bout1 − Bout2	−2.66	(-7.48,2.17)	0.399
		Bout1 − Bout3	−3.32	(-8.21,1.57)	0.249
		Bout2 − Bout3	−0.66	(-5.55,4.23)	0.946
RPE (6-20) *2 / 1004 Bouts with missing measurements.*	S : 3v3	Bout1 − Bout2	−1.92	(-3.17,-0.68)	<0.001
		Bout1 − Bout3	−1.77	(-3.01,-0.53)	0.002
		Bout2 − Bout3	0.15	(-1.09,1.40)	0.954
	S : 5v5	Bout1 − Bout2	−2.11	(-4.22,0.00)	0.050
		Bout1 − Bout3	−2.56	(-4.67,-0.44)	0.013
		Bout2 − Bout3	−0.44	(-2.56,1.67)	0.874
	S : 7v7	Bout1 − Bout2	−1.60	(-3.60,0.40)	0.146
		Bout1 − Bout3	−3.10	(-5.10,-1.10)	<0.001
		Bout2 − Bout3	−1.50	(-3.50,0.50)	0.184
	M : 3v3	Bout1 − Bout2	−0.98	(-2.59,0.63)	0.324
		Bout1 − Bout3	−1.73	(-3.37,-0.10)	0.035
		Bout2 − Bout3	−0.75	(-2.36,0.86)	0.518
	M : 5v5	Bout1 − Bout2	−1.37	(-3.61,0.86)	0.320
		Bout1 − Bout3	−3.37	(-5.61,-1.14)	0.001
		Bout2 − Bout3	−2.00	(-4.24,0.24)	0.091
	M : 7v7	Bout1 − Bout2	−0.50	(-2.50,1.50)	0.828
		Bout1 − Bout3	−1.90	(-3.90,0.10)	0.067

U18	Pitch * No.	Comparison	Estimate	95% Adj. C.I.	Adj. *p*-value
		Bout2 − Bout3	−1.40	(-3.40,0.60)	0.229
	L : 3v3	Bout1 − Bout2	−1.36	(-2.92,0.20)	0.101
		Bout1 − Bout3	−2.31	(-3.90,-0.72)	0.002
		Bout2 − Bout3	−0.95	(-2.56,0.66)	0.352
	L : 5v5	Bout1 − Bout2	−1.74	(-3.19,-0.28)	0.014
		Bout1 − Bout3	−3.05	(-4.51,-1.60)	<0.001
		Bout2 − Bout3	−1.32	(-2.77,0.14)	0.085
	L : 7v7	Bout1 − Bout2	−0.63	(-2.08,0.82)	0.564
		Bout1 − Bout3	−0.55	(-2.03,0.92)	0.653
		Bout2 − Bout3	0.08	(-1.39,1.55)	0.991
Sprint·min^{-1}	S : 3v3	Bout1 − Bout2	−0.15	(-0.89,0.59)	0.882
47 / 1004 Bouts with missing measurements.		Bout1 − Bout3	0.10	(-0.64,0.84)	0.946
		Bout2 − Bout3	0.25	(-0.49,0.99)	0.705
	S : 5v5	Bout1 − Bout2	−0.54	(-1.93,0.86)	0.638
		Bout1 − Bout3	−0.43	(-1.82,0.96)	0.750
		Bout2 − Bout3	0.11	(-1.29,1.50)	0.982
	S : 7v7	Bout1 − Bout2	0.02	(-1.14,1.19)	0.999
		Bout1 − Bout3	−0.58	(-1.74,0.59)	0.478
		Bout2 − Bout3	−0.60	(-1.76,0.56)	0.448
	M : 3v3	Bout1 − Bout2	0.07	(-0.87,1.00)	0.984
		Bout1 − Bout3	0.38	(-0.57,1.33)	0.611
		Bout2 − Bout3	0.32	(-0.62,1.25)	0.708
	M : 5v5	Bout1 − Bout2	0.63	(-0.88,2.13)	0.592
		Bout1 − Bout3	−0.54	(-2.05,0.96)	0.675
		Bout2 − Bout3	−1.17	(-2.67,0.34)	0.163
	M : 7v7	Bout1 − Bout2	0.83	(-0.34,1.99)	0.220
		Bout1 − Bout3	1.13	(-0.04,2.29)	0.061
		Bout2 − Bout3	0.30	(-0.86,1.46)	0.818
	L : 3v3	Bout1 − Bout2	0.23	(-0.68,1.14)	0.824
		Bout1 − Bout3	−0.01	(-0.93,0.91)	1.000
		Bout2 − Bout3	−0.24	(-1.18,0.70)	0.818
	L : 5v5	Bout1 − Bout2	0.14	(-0.70,0.99)	0.915
		Bout1 − Bout3	0.67	(-0.17,1.52)	0.150
		Bout2 − Bout3	0.53	(-0.32,1.37)	0.310
	L : 7v7	Bout1 − Bout2	0.63	(-0.21,1.48)	0.186
		Bout1 − Bout3	0.59	(-0.27,1.44)	0.243
		Bout2 − Bout3	−0.04	(-0.90,0.81)	0.992
HIacc	S : 3v3	Bout1 − Bout2	−0.36	(-3.16,2.44)	0.951
47 / 1004 Bouts with missing measurements.		Bout1 − Bout3	1.68	(-1.12,4.48)	0.336
		Bout2 − Bout3	2.04	(-0.76,4.84)	0.201
	S : 5v5	Bout1 − Bout2	−3.14	(-8.43,2.15)	0.344
		Bout1 − Bout3	−1.71	(-7.00,3.57)	0.727
		Bout2 − Bout3	1.43	(-3.86,6.72)	0.801
	S : 7v7	Bout1 − Bout2	0.60	(-3.82,5.02)	0.946
		Bout1 − Bout3	0.50	(-3.92,4.92)	0.962

U18	Pitch * No.	Comparison	Estimate	95% Adj. C.I.	Adj. *p*-value
		Bout2 − Bout3	−0.10	(-4.52,4.32)	0.998
	M : 3v3	Bout1 − Bout2	1.25	(-2.31,4.81)	0.687
		Bout1 − Bout3	1.87	(-1.75,5.48)	0.446
		Bout2 − Bout3	0.62	(-2.94,4.17)	0.913
	M : 5v5	Bout1 − Bout2	1.17	(-4.55,6.88)	0.881
		Bout1 − Bout3	1.50	(-4.21,7.21)	0.811
		Bout2 − Bout3	0.33	(-5.38,6.05)	0.990
	M : 7v7	Bout1 − Bout2	1.40	(-3.02,5.82)	0.738
		Bout1 − Bout3	3.10	(-1.32,7.52)	0.227
		Bout2 − Bout3	1.70	(-2.72,6.12)	0.639
	L : 3v3	Bout1 − Bout2	1.85	(-1.60,5.30)	0.418
		Bout1 − Bout3	1.41	(-2.09,4.92)	0.612
		Bout2 − Bout3	−0.44	(-3.99,3.12)	0.955
	L : 5v5	Bout1 − Bout2	0.58	(-2.63,3.79)	0.906
		Bout1 − Bout3	2.47	(-0.74,5.68)	0.167
		Bout2 − Bout3	1.89	(-1.32,5.10)	0.349
	L : 7v7	Bout1 − Bout2	3.16	(-0.05,6.37)	0.055
		Bout1 − Bout3	2.26	(-0.99,5.52)	0.232
		Bout2 − Bout3	−0.89	(-4.15,2.36)	0.795
HIdec	S : 3v3	Bout1 − Bout2	0.12	(-1.21,1.45)	0.976
47 / 1004 Bouts with missing measurements.		Bout1 − Bout3	−0.08	(-1.41,1.25)	0.989
		Bout2 − Bout3	−0.20	(-1.53,1.13)	0.934
	S : 5v5	Bout1 − Bout2	−1.14	(-3.66,1.38)	0.536
		Bout1 − Bout3	−1.29	(-3.81,1.23)	0.455
		Bout2 − Bout3	−0.14	(-2.66,2.38)	0.990
	S : 7v7	Bout1 − Bout2	0.70	(-1.41,2.81)	0.716
		Bout1 − Bout3	−0.80	(-2.91,1.31)	0.646
		Bout2 − Bout3	−1.50	(-3.61,0.61)	0.217
	M : 3v3	Bout1 − Bout2	0.59	(-1.11,2.28)	0.694
		Bout1 − Bout3	1.07	(-0.66,2.79)	0.314
		Bout2 − Bout3	0.48	(-1.22,2.17)	0.785
	M : 5v5	Bout1 − Bout2	−0.33	(-3.06,2.39)	0.955
		Bout1 − Bout3	−0.83	(-3.56,1.89)	0.752
		Bout2 − Bout3	−0.50	(-3.22,2.22)	0.903
	M : 7v7	Bout1 − Bout2	−0.20	(-2.31,1.91)	0.973
		Bout1 − Bout3	1.00	(-1.11,3.11)	0.506
		Bout2 − Bout3	1.20	(-0.91,3.31)	0.376
	L : 3v3	Bout1 − Bout2	0.44	(-1.20,2.09)	0.800
		Bout1 − Bout3	0.62	(-1.05,2.29)	0.662
		Bout2 − Bout3	0.17	(-1.52,1.87)	0.970
	L : 5v5	Bout1 − Bout2	0.26	(-1.27,1.79)	0.914
		Bout1 − Bout3	0.74	(-0.79,2.27)	0.495
		Bout2 − Bout3	0.47	(-1.06,2.00)	0.748
	L : 7v7	Bout1 − Bout2	0.63	(-0.90,2.16)	0.597
		Bout1 − Bout3	0.03	(-1.52,1.58)	0.999

U18	Pitch * No.	Comparison	Estimate	95% Adj. C.I.	Adj. *p*-value
		Bout2 − Bout3	−0.60	(-2.15,0.95)	0.633
AL_{3D} (AU) *44 / 1004 Bouts with missing measurements.*	S : 3v3	Bout1 − Bout2	−0.02	(-0.64,0.59)	0.995
		Bout1 − Bout3	0.37	(-0.25,0.99)	0.337
		Bout2 − Bout3	0.40	(-0.22,1.01)	0.290
	S : 5v5	Bout1 − Bout2	−0.53	(-1.67,0.62)	0.524
		Bout1 − Bout3	−0.27	(-1.42,0.87)	0.843
		Bout2 − Bout3	0.26	(-0.89,1.40)	0.858
	S : 7v7	Bout1 − Bout2	0.16	(-0.80,1.12)	0.919
		Bout1 − Bout3	−0.18	(-1.14,0.78)	0.898
		Bout2 − Bout3	−0.34	(-1.30,0.62)	0.682
	M : 3v3	Bout1 − Bout2	0.24	(-0.53,1.01)	0.750
		Bout1 − Bout3	0.67	(-0.12,1.45)	0.112
		Bout2 − Bout3	0.43	(-0.34,1.20)	0.389
	M : 5v5	Bout1 − Bout2	0.84	(-0.51,2.19)	0.313
		Bout1 − Bout3	0.37	(-0.92,1.67)	0.778
		Bout2 − Bout3	−0.47	(-1.76,0.83)	0.675
	M : 7v7	Bout1 − Bout2	0.14	(-0.82,1.10)	0.937
		Bout1 − Bout3	0.64	(-0.32,1.60)	0.260
		Bout2 − Bout3	0.50	(-0.46,1.46)	0.438
	L : 3v3	Bout1 − Bout2	0.54	(-0.23,1.31)	0.232
		Bout1 − Bout3	0.34	(-0.43,1.11)	0.562
		Bout2 − Bout3	−0.20	(-0.98,0.58)	0.820
	L : 5v5	Bout1 − Bout2	0.25	(-0.46,0.96)	0.689
		Bout1 − Bout3	0.29	(-0.42,1.01)	0.597
		Bout2 − Bout3	0.04	(-0.67,0.76)	0.988
	L : 7v7	Bout1 − Bout2	0.73	(0.04,1.43)	0.036
		Bout1 − Bout3	0.71	(0.00,1.41)	0.048
		Bout2 − Bout3	−0.02	(-0.73,0.68)	0.997
Impact (min^{-1}) *47 / 1004 Bouts with missing measurements.*	S : 3v3	Bout1 − Bout2	−0.02	(-0.07,0.03)	0.599
		Bout1 − Bout3	−0.02	(-0.07,0.03)	0.599
		Bout2 − Bout3	0.00	(-0.05,0.05)	1.000
	S : 5v5	Bout1 − Bout2	−0.00	(-0.09,0.09)	1.000
		Bout1 − Bout3	−0.00	(-0.09,0.09)	1.000
		Bout2 − Bout3	0.00	(-0.09,0.09)	1.000
	S : 7v7	Bout1 − Bout2	−0.00	(-0.08,0.08)	1.000
		Bout1 − Bout3	−0.00	(-0.08,0.08)	1.000
		Bout2 − Bout3	0.00	(-0.08,0.08)	1.000
	M : 3v3	Bout1 − Bout2	0.02	(-0.05,0.08)	0.802
		Bout1 − Bout3	−0.05	(-0.11,0.01)	0.148
		Bout2 − Bout3	−0.07	(-0.13,-0.00)	0.031
	M : 5v5	Bout1 − Bout2	−0.00	(-0.10,0.10)	1.000
		Bout1 − Bout3	−0.04	(-0.14,0.06)	0.586
		Bout2 − Bout3	−0.04	(-0.14,0.06)	0.586
	M : 7v7	Bout1 − Bout2	−0.00	(-0.08,0.08)	1.000
		Bout1 − Bout3	0.03	(-0.05,0.10)	0.726

U18	Pitch * No.	Comparison	Estimate	95% Adj. C.I.	Adj. *p*-value
		Bout2 − Bout3	0.03	(-0.05,0.10)	0.726
	L : 3v3	Bout1 − Bout2	0.01	(-0.05,0.07)	0.851
		Bout1 − Bout3	−0.02	(-0.08,0.04)	0.707
		Bout2 − Bout3	−0.03	(-0.10,0.03)	0.392
	L : 5v5	Bout1 − Bout2	−0.01	(-0.07,0.04)	0.845
		Bout1 − Bout3	0.00	(-0.06,0.06)	1.000
		Bout2 − Bout3	0.01	(-0.04,0.07)	0.845
	L : 7v7	Bout1 − Bout2	−0.03	(-0.08,0.03)	0.510
		Bout1 − Bout3	−0.04	(-0.10,0.01)	0.195
		Bout2 − Bout3	−0.02	(-0.07,0.04)	0.800
HIRD (m)	S : 3v3	Bout1 − Bout2	−1.00	(-15.51,13.51)	0.986
101 / 1004 Bouts with missing measurements.		Bout1 − Bout3	−3.13	(-17.64,11.38)	0.868
		Bout2 − Bout3	−2.13	(-16.64,12.38)	0.937
	S : 5v5	Bout1 − Bout2	−0.00	(-26.30,26.30)	1.000
		Bout1 − Bout3	−6.29	(-32.58,20.01)	0.841
		Bout2 − Bout3	−6.29	(-32.58,20.01)	0.841
	S : 7v7	Bout1 − Bout2	1.10	(-20.90,23.10)	0.992
		Bout1 − Bout3	0.60	(-21.40,22.60)	0.998
		Bout2 − Bout3	−0.50	(-22.50,21.50)	0.998
	M : 3v3	Bout1 − Bout2	4.65	(-13.03,22.33)	0.811
		Bout1 − Bout3	5.40	(-12.56,23.36)	0.760
		Bout2 − Bout3	0.75	(-16.93,18.43)	0.995
	M : 5v5	Bout1 − Bout2	13.00	(-18.12,44.12)	0.589
		Bout1 − Bout3	15.90	(-13.89,45.69)	0.422
		Bout2 − Bout3	2.90	(-26.89,32.69)	0.972
	M : 7v7	Bout1 − Bout2	−18.50	(-40.50,3.50)	0.119
		Bout1 − Bout3	−11.80	(-33.80,10.20)	0.419
		Bout2 − Bout3	6.70	(-15.30,28.70)	0.755
	L : 3v3	Bout1 − Bout2	3.77	(-13.91,21.46)	0.871
		Bout1 − Bout3	6.24	(-11.44,23.92)	0.685
		Bout2 − Bout3	2.47	(-15.50,20.43)	0.944
	L : 5v5	Bout1 − Bout2	−1.01	(-17.65,15.63)	0.989
		Bout1 − Bout3	−14.51	(-31.15,2.13)	0.102
		Bout2 − Bout3	−13.50	(-29.90,2.90)	0.130
	L : 7v7	Bout1 − Bout2	15.68	(-0.28,31.65)	0.055
		Bout1 − Bout3	13.44	(-2.75,29.62)	0.126
		Bout2 − Bout3	−2.25	(-18.43,13.93)	0.943
HSRD (m)	S : 3v3	Bout1 − Bout2	−1.04	(-12.84,10.75)	0.976
101 / 1004 Bouts with missing measurements.		Bout1 − Bout3	−2.35	(-14.14,9.45)	0.887
		Bout2 − Bout3	−1.30	(-13.10,10.49)	0.964
	S : 5v5	Bout1 − Bout2	−1.00	(-22.38,20.38)	0.993
		Bout1 − Bout3	−4.57	(-25.95,16.81)	0.870
		Bout2 − Bout3	−3.57	(-24.95,17.81)	0.919
	S : 7v7	Bout1 − Bout2	0.30	(-17.59,18.19)	0.999
		Bout1 − Bout3	−0.40	(-18.29,17.49)	0.998

U18	Pitch * No.	Comparison	Estimate	95% Adj. C.I.	Adj. *p*-value
		Bout2 − Bout3	−0.70	(-18.59,17.19)	0.995
	M : 3v3	Bout1 − Bout2	2.10	(-12.28,16.48)	0.937
		Bout1 − Bout3	6.20	(-8.41,20.81)	0.579
		Bout2 − Bout3	4.10	(-10.28,18.48)	0.781
	M : 5v5	Bout1 − Bout2	9.60	(-15.70,34.90)	0.646
		Bout1 − Bout3	8.87	(-15.36,33.09)	0.666
		Bout2 − Bout3	−0.73	(-24.96,23.49)	0.997
	M : 7v7	Bout1 − Bout2	−16.90	(-34.79,0.99)	0.069
		Bout1 − Bout3	−9.80	(-27.69,8.09)	0.403
		Bout2 − Bout3	7.10	(-10.79,24.99)	0.620
	L : 3v3	Bout1 − Bout2	5.25	(-9.12,19.63)	0.667
		Bout1 − Bout3	4.39	(-9.99,18.76)	0.754
		Bout2 − Bout3	−0.87	(-15.47,13.74)	0.989
	L : 5v5	Bout1 − Bout2	0.53	(-13.00,14.06)	0.995
		Bout1 − Bout3	−13.75	(-27.27,-0.22)	0.045
		Bout2 − Bout3	−14.28	(-27.61,-0.94)	0.032
	L : 7v7	Bout1 − Bout2	9.95	(-3.03,22.93)	0.170
		Bout1 − Bout3	9.39	(-3.76,22.55)	0.215
		Bout2 − Bout3	−0.55	(-13.71,12.60)	0.995
VHSRD (m)	S : 3v3	Bout1 − Bout2	−2.09	(-7.87,3.70)	0.674
103 / 1004 Bouts with missing measurements.		Bout1 − Bout3	−1.04	(-6.83,4.74)	0.906
		Bout2 − Bout3	1.04	(-4.74,6.83)	0.906
	S : 5v5	Bout1 − Bout2	−0.14	(-10.63,10.35)	0.999
		Bout1 − Bout3	−0.00	(-10.49,10.49)	1.000
		Bout2 − Bout3	0.14	(-10.35,10.63)	0.999
	S : 7v7	Bout1 − Bout2	−0.00	(-8.78,8.78)	1.000
		Bout1 − Bout3	−0.00	(-8.78,8.78)	1.000
		Bout2 − Bout3	0.00	(-8.78,8.78)	1.000
	M : 3v3	Bout1 − Bout2	1.92	(-5.14,8.97)	0.799
		Bout1 − Bout3	3.00	(-4.17,10.17)	0.588
		Bout2 − Bout3	1.08	(-5.97,8.14)	0.931
	M : 5v5	Bout1 − Bout2	4.80	(-7.61,17.21)	0.635
		Bout1 − Bout3	7.33	(-4.55,19.22)	0.316
		Bout2 − Bout3	2.53	(-9.35,14.42)	0.871
	M : 7v7	Bout1 − Bout2	−7.30	(-16.08,1.48)	0.125
		Bout1 − Bout3	−3.90	(-12.68,4.88)	0.550
		Bout2 − Bout3	3.40	(-5.38,12.18)	0.634
	L : 3v3	Bout1 − Bout2	3.63	(-3.42,10.68)	0.449
		Bout1 − Bout3	2.10	(-4.96,9.15)	0.765
		Bout2 − Bout3	−1.53	(-8.70,5.63)	0.870
	L : 5v5	Bout1 − Bout2	−0.92	(-7.56,5.71)	0.943
		Bout1 − Bout3	−4.81	(-11.45,1.83)	0.205
		Bout2 − Bout3	−3.89	(-10.43,2.65)	0.343
	L : 7v7	Bout1 − Bout2	2.63	(-3.74,9.00)	0.596
		Bout1 − Bout3	1.57	(-4.88,8.03)	0.835
		Bout2 − Bout3	−1.06	(-7.51,5.40)	0.922

Appendix 15: Youth SSG formats bout differences – Speed zones (imputed values R)

Statistically significantly different (*p*≤ *0.05*)
Trend to significancy (*p*= *0.05-0.1*)

YOUTH	Pitch * No.	Comparison	Estimate	95% Adj. C.I.	Adj. *p*-value
V_{Z1} (m)	S : 3v3	Bout1 − Bout2	−2.38	(-15.40,10.63)	0.903
101 out of 1004 Bouts had missing measurements.		Bout1 − Bout3	−4.85	(-17.52,7.81)	0.640
		Bout2 − Bout3	−2.47	(-15.56,10.62)	0.898
	S : 5v5	Bout1 − Bout2	−8.79	(-24.01,6.44)	0.365
		Bout1 − Bout3	−3.23	(-20.44,13.98)	0.899
		Bout2 − Bout3	5.56	(-11.66,22.77)	0.729
	S : 7v7	Bout1 − Bout2	3.23	(-12.57,19.03)	0.881
		Bout1 − Bout3	9.97	(-5.99,25.93)	0.307
		Bout2 − Bout3	6.74	(-9.22,22.70)	0.582
	M : 3v3	Bout1 − Bout2	−5.55	(-17.69,6.60)	0.532
		Bout1 − Bout3	−5.30	(-17.83,7.23)	0.581
		Bout2 − Bout3	0.24	(-12.29,12.77)	0.999
	M : 5v5	Bout1 − Bout2	−27.81	(-47.96,-7.67)	0.004
		Bout1 − Bout3	−18.76	(-38.61,1.08)	0.068
		Bout2 − Bout3	9.05	(-10.80,28.89)	0.533
	M : 7v7	Bout1 − Bout2	−12.70	(-24.58,-0.82)	0.033
		Bout1 − Bout3	−9.89	(-21.71,1.93)	0.122
		Bout2 − Bout3	2.81	(-9.01,14.62)	0.843
	L : 3v3	Bout1 − Bout2	−10.85	(-24.67,2.97)	0.156
		Bout1 − Bout3	−13.68	(-27.49,0.14)	0.053
		Bout2 − Bout3	−2.82	(-16.64,10.99)	0.881
	L : 5v5	Bout1 − Bout2	−3.35	(-18.72,12.01)	0.865
		Bout1 − Bout3	−3.75	(-19.11,11.62)	0.835
		Bout2 − Bout3	−0.39	(-15.62,14.83)	0.998
	L : 7v7	Bout1 − Bout2	−12.56	(-23.95,-1.17)	0.027
		Bout1 − Bout3	−7.86	(-20.41,4.70)	0.306
		Bout2 − Bout3	4.70	(-7.85,17.26)	0.654
V_{Z2} (m)	S : 3v3	Bout1 − Bout2	13.88	(-16.34,44.09)	0.528
101 out of 1004 Bouts had missing measurements.		Bout1 − Bout3	41.17	(11.77,70.57)	0.003
		Bout2 − Bout3	27.30	(-3.10,57.69)	0.089
	S : 5v5	Bout1 − Bout2	−6.39	(-41.75,28.96)	0.905
		Bout1 − Bout3	−20.97	(-60.94,19.00)	0.435
		Bout2 − Bout3	−14.58	(-54.54,25.39)	0.668
	S : 7v7	Bout1 − Bout2	2.92	(-33.77,39.62)	0.981
		Bout1 − Bout3	2.46	(-34.60,39.52)	0.987
		Bout2 − Bout3	−0.46	(-37.52,36.59)	1.000
	M : 3v3	Bout1 − Bout2	8.89	(-19.32,37.09)	0.740
		Bout1 − Bout3	19.55	(-9.55,48.65)	0.256
		Bout2 − Bout3	10.66	(-18.43,39.76)	0.665
	M : 5v5	Bout1 − Bout2	21.25	(-25.52,68.02)	0.535

YOUTH	Pitch * No.	Comparison	Estimate	95% Adj. C.I.	Adj. *p*-value
		Bout1 − Bout3	22.89	(-23.19,68.97)	0.474
		Bout2 − Bout3	1.64	(-44.44,47.72)	0.996
	M : 7v7	Bout1 − Bout2	8.80	(-18.78,36.39)	0.734
		Bout1 − Bout3	14.23	(-13.21,41.67)	0.443
		Bout2 − Bout3	5.42	(-22.01,32.86)	0.888
	L : 3v3	Bout1 − Bout2	29.44	(-2.65,61.53)	0.080
		Bout1 − Bout3	34.88	(2.80,66.97)	0.029
		Bout2 − Bout3	5.44	(-26.65,37.53)	0.916
	L : 5v5	Bout1 − Bout2	15.39	(-20.29,51.08)	0.569
		Bout1 − Bout3	42.25	(6.57,77.93)	0.015
		Bout2 − Bout3	26.86	(-8.50,62.21)	0.176
	L : 7v7	Bout1 − Bout2	16.08	(-10.38,42.54)	0.328
		Bout1 − Bout3	0.05	(-29.11,29.21)	1.000
		Bout2 − Bout3	−16.03	(-45.19,13.13)	0.401
V_{Z3} (m)	S : 3v3	Bout1 − Bout2	1.99	(-11.91,15.90)	0.940
101 out of 1004		Bout1 − Bout3	0.81	(-12.72,14.34)	0.989
Bouts had missing measurements.		Bout2 − Bout3	−1.18	(-15.17,12.80)	0.978
	S : 5v5	Bout1 − Bout2	−8.68	(-24.95,7.59)	0.423
		Bout1 − Bout3	−9.55	(-27.94,8.84)	0.442
		Bout2 − Bout3	−0.87	(-19.26,17.52)	0.993
	S : 7v7	Bout1 − Bout2	5.42	(-11.46,22.31)	0.731
		Bout1 − Bout3	1.34	(-15.71,18.39)	0.981
		Bout2 − Bout3	−4.08	(-21.14,12.97)	0.840
	M : 3v3	Bout1 − Bout2	−5.89	(-18.86,7.09)	0.536
		Bout1 − Bout3	8.44	(-4.94,21.83)	0.301
		Bout2 − Bout3	14.33	(0.94,27.72)	0.033
	M : 5v5	Bout1 − Bout2	−2.25	(-23.77,19.27)	0.967
		Bout1 − Bout3	3.70	(-17.50,24.90)	0.912
		Bout2 − Bout3	5.95	(-15.25,27.15)	0.787
	M : 7v7	Bout1 − Bout2	−0.04	(-12.74,12.65)	1.000
		Bout1 − Bout3	−16.07	(-28.69,-3.44)	0.008
		Bout2 − Bout3	−16.02	(-28.65,-3.40)	0.008
	L : 3v3	Bout1 − Bout2	0.88	(-13.88,15.65)	0.989
		Bout1 − Bout3	3.76	(-11.00,18.53)	0.821
		Bout2 − Bout3	2.88	(-11.88,17.65)	0.891
	L : 5v5	Bout1 − Bout2	8.05	(-8.37,24.47)	0.483
		Bout1 − Bout3	3.30	(-13.12,19.72)	0.884
		Bout2 − Bout3	−4.75	(-21.02,11.52)	0.772
	L : 7v7	Bout1 − Bout2	8.16	(-4.01,20.33)	0.258
		Bout1 − Bout3	6.68	(-6.74,20.09)	0.472
		Bout2 − Bout3	−1.48	(-14.90,11.93)	0.964
V_{Z4} (m)	S : 3v3	Bout1 − Bout2	−0.22	(-3.53,3.09)	0.986
		Bout1 − Bout3	0.50	(-2.72,3.72)	0.930
		Bout2 − Bout3	0.72	(-2.61,4.05)	0.867

YOUTH	Pitch * No.	Comparison	Estimate	95% Adj. C.I.	Adj. *p*-value
101 out of 1004 Bouts had missing measurements.	S : 5v5	Bout1 − Bout2	−0.71	(-4.59,3.16)	0.902
		Bout1 − Bout3	0.07	(-4.31,4.45)	0.999
		Bout2 − Bout3	0.79	(-3.60,5.17)	0.907
	S : 7v7	Bout1 − Bout2	0.42	(-3.60,4.45)	0.967
		Bout1 − Bout3	0.50	(-3.57,4.56)	0.956
		Bout2 − Bout3	0.07	(-3.99,4.13)	0.999
	M : 3v3	Bout1 − Bout2	−0.64	(-3.73,2.46)	0.879
		Bout1 − Bout3	0.37	(-2.82,3.56)	0.959
		Bout2 − Bout3	1.01	(-2.18,4.20)	0.737
	M : 5v5	Bout1 − Bout2	1.63	(-3.50,6.75)	0.737
		Bout1 − Bout3	0.94	(-4.11,5.99)	0.901
		Bout2 − Bout3	−0.69	(-5.74,4.36)	0.945
	M : 7v7	Bout1 − Bout2	−2.24	(-5.26,0.78)	0.192
		Bout1 − Bout3	−1.53	(-4.54,1.48)	0.458
		Bout2 − Bout3	0.71	(-2.30,3.72)	0.844
	L : 3v3	Bout1 − Bout2	2.97	(-0.55,6.49)	0.117
		Bout1 − Bout3	0.38	(-3.14,3.90)	0.965
		Bout2 − Bout3	−2.59	(-6.11,0.93)	0.195
	L : 5v5	Bout1 − Bout2	−0.80	(-4.72,3.11)	0.880
		Bout1 − Bout3	−2.66	(-6.57,1.25)	0.247
		Bout2 − Bout3	−1.86	(-5.73,2.02)	0.499
	L : 7v7	Bout1 − Bout2	1.30	(-1.60,4.20)	0.544
		Bout1 − Bout3	0.22	(-2.97,3.42)	0.985
		Bout2 − Bout3	−1.08	(-4.27,2.12)	0.709
V_{Z5} (m)	S : 3v3	Bout1 − Bout2	−0.06	(-0.68,0.56)	0.973
101 out of 1004 Bouts had missing measurements.		Bout1 − Bout3	0.02	(-0.58,0.63)	0.995
		Bout2 − Bout3	0.08	(-0.54,0.70)	0.947
	S : 5v5	Bout1 − Bout2	−0.07	(-0.79,0.65)	0.971
		Bout1 − Bout3	0.00	(-0.82,0.82)	1.000
		Bout2 − Bout3	0.07	(-0.75,0.89)	0.977
	S : 7v7	Bout1 − Bout2	−0.08	(-0.83,0.67)	0.969
		Bout1 − Bout3	−0.00	(-0.76,0.76)	1.000
		Bout2 − Bout3	0.08	(-0.68,0.83)	0.969
	M : 3v3	Bout1 − Bout2	0.20	(-0.37,0.78)	0.683
		Bout1 − Bout3	0.23	(-0.37,0.82)	0.642
		Bout2 − Bout3	0.02	(-0.57,0.62)	0.996
	M : 5v5	Bout1 − Bout2	0.00	(-0.96,0.96)	1.000
		Bout1 − Bout3	0.00	(-0.94,0.94)	1.000
		Bout2 − Bout3	−0.00	(-0.94,0.94)	1.000
	M : 7v7	Bout1 − Bout2	0.15	(-0.41,0.72)	0.802
		Bout1 − Bout3	0.07	(-0.49,0.63)	0.955
		Bout2 − Bout3	−0.08	(-0.64,0.48)	0.935
	L : 3v3	Bout1 − Bout2	1.35	(0.70,2.01)	<0.001

YOUTH	Pitch * No.	Comparison	Estimate	95% Adj. C.I.	Adj. *p*-value
		Bout1 − Bout3	1.26	(0.61,1.92)	<0.001
		Bout2 − Bout3	−0.09	(-0.74,0.57)	0.946
	L : 5v5	Bout1 − Bout2	0.01	(-0.72,0.73)	1.000
		Bout1 − Bout3	0.04	(-0.69,0.77)	0.990
		Bout2 − Bout3	0.04	(-0.69,0.76)	0.993
	L : 7v7	Bout1 − Bout2	0.06	(-0.48,0.60)	0.963
		Bout1 − Bout3	−0.07	(-0.67,0.52)	0.957
		Bout2 − Bout3	−0.13	(-0.73,0.46)	0.863

U14	Pitch * No.	Comparison	Estimate	95% Adj. C.I.	Adj. *p*-value
V_{Z1} (m)	S : 3v3	Bout1 − Bout2	0.74	(-27.02,28.51)	0.998
101 / 1004 Bouts with missing measurements.		Bout1 − Bout3	−7.89	(-31.79,16.01)	0.718
		Bout2 − Bout3	−8.63	(-36.88,19.62)	0.753
	S : 5v5	Bout1 − Bout2	−12.50	(-36.96,11.96)	0.454
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	S : 7v7	Bout1 − Bout2	—		
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	M : 3v3	Bout1 − Bout2	−7.14	(-27.82,13.53)	0.696
		Bout1 − Bout3	2.97	(-20.40,26.34)	0.952
		Bout2 − Bout3	10.11	(-13.26,33.48)	0.567
	M : 5v5	Bout1 − Bout2	−25.70	(-50.16,-1.24)	0.037
		Bout1 − Bout3	−25.40	(-49.86,-0.94)	0.040
		Bout2 − Bout3	0.30	(-24.16,24.76)	1.000
	M : 7v7	Bout1 − Bout2	−32.62	(-59.98,-5.27)	0.014
		Bout1 − Bout3	−16.87	(-44.23,10.48)	0.317
		Bout2 − Bout3	15.75	(-11.60,43.10)	0.367
	L : 3v3	Bout1 − Bout2	−25.33	(-54.88,4.21)	0.110
		Bout1 − Bout3	−44.08	(-73.63,-14.54)	0.001
		Bout2 − Bout3	−18.75	(-46.10,8.60)	0.242
	L : 5v5	Bout1 − Bout2	—		
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	L : 7v7	Bout1 − Bout2	−11.29	(-31.96,9.39)	0.406
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
V_{Z2} (m)	S : 3v3	Bout1 − Bout2	27.21	(-32.98,87.41)	0.538
101 / 1004 Bouts with missing measurements.		Bout1 − Bout3	72.05	(20.22,123.87)	0.003
		Bout2 − Bout3	44.83	(-16.41,106.08)	0.199
	S : 5v5	Bout1 − Bout2	1.70	(-51.34,54.74)	0.997
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	S : 7v7	Bout1 − Bout2	—		
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	M : 3v3	Bout1 − Bout2	6.50	(-38.33,51.33)	0.938
		Bout1 − Bout3	−11.84	(-62.51,38.83)	0.847
		Bout2 − Bout3	−18.34	(-69.01,32.33)	0.672
	M : 5v5	Bout1 − Bout2	13.20	(-39.84,66.24)	0.829
		Bout1 − Bout3	38.90	(-14.14,91.94)	0.198
		Bout2 − Bout3	25.70	(-27.34,78.74)	0.491
	M : 7v7	Bout1 − Bout2	−64.62	(-123.93,-5.32)	0.029
		Bout1 − Bout3	−9.12	(-68.43,50.18)	0.931
		Bout2 − Bout3	55.50	(-3.80,114.80)	0.072

U14	Pitch * No.	Comparison	Estimate	95% Adj. C.I.	Adj. *p*-value
	L : 3v3	Bout1 − Bout2	28.33	(-35.72,92.39)	0.553
		Bout1 − Bout3	70.08	(6.03,134.14)	0.028
		Bout2 − Bout3	41.75	(-17.55,101.05)	0.224
	L : 5v5	Bout1 − Bout2	—		
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	L : 7v7	Bout1 − Bout2	−1.07	(-45.90,43.76)	0.998
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
V_{Z3} (m)	S : 3v3	Bout1 − Bout2	11.24	(-17.16,39.64)	0.622
101 / 1004 Bouts with missing measurements.		Bout1 − Bout3	4.61	(-19.84,29.06)	0.898
		Bout2 − Bout3	−6.63	(-35.53,22.26)	0.852
	S : 5v5	Bout1 − Bout2	−11.80	(-36.83,13.23)	0.510
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	S : 7v7	Bout1 − Bout2	—		
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	M : 3v3	Bout1 − Bout2	−13.21	(-34.37,7.94)	0.307
		Bout1 − Bout3	−2.90	(-26.81,21.01)	0.956
		Bout2 − Bout3	10.32	(-13.59,34.23)	0.569
	M : 5v5	Bout1 − Bout2	−9.70	(-34.73,15.33)	0.634
		Bout1 − Bout3	0.90	(-24.13,25.93)	0.996
		Bout2 − Bout3	10.60	(-14.43,35.63)	0.581
	M : 7v7	Bout1 − Bout2	−5.00	(-32.98,22.98)	0.908
		Bout1 − Bout3	−15.00	(-42.98,12.98)	0.419
		Bout2 − Bout3	−10.00	(-37.98,17.98)	0.679
	L : 3v3	Bout1 − Bout2	−2.50	(-32.72,27.72)	0.979
		Bout1 − Bout3	18.63	(-11.60,48.85)	0.317
		Bout2 − Bout3	21.12	(-6.86,49.11)	0.179
	L : 5v5	Bout1 − Bout2	—		
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	L : 7v7	Bout1 − Bout2	3.21	(-17.94,24.37)	0.932
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
V_{Z4} (m)	S : 3v3	Bout1 − Bout2	1.18	(-6.21,8.58)	0.925
101 / 1004 Bouts with missing measurements.		Bout1 − Bout3	1.18	(-5.19,7.55)	0.901
		Bout2 − Bout3	−0.00	(-7.53,7.53)	1.000
	S : 5v5	Bout1 − Bout2	−1.00	(-7.52,5.52)	0.931
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	S : 7v7	Bout1 − Bout2	—		
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		

U14	Pitch * No.	Comparison	Estimate	95% Adj. C.I.	Adj. *p*-value
	M : 3v3	Bout1 − Bout2	−1.07	(-6.58,4.44)	0.891
		Bout1 − Bout3	0.51	(-5.72,6.73)	0.980
		Bout2 − Bout3	1.58	(-4.65,7.81)	0.823
	M : 5v5	Bout1 − Bout2	−0.50	(-7.02,6.02)	0.982
		Bout1 − Bout3	−1.90	(-8.42,4.62)	0.773
		Bout2 − Bout3	−1.40	(-7.92,5.12)	0.869
	M : 7v7	Bout1 − Bout2	0.00	(-7.29,7.29)	1.000
		Bout1 − Bout3	−0.38	(-7.66,6.91)	0.992
		Bout2 − Bout3	−0.38	(-7.66,6.91)	0.992
	L : 3v3	Bout1 − Bout2	−0.21	(-8.08,7.66)	0.998
		Bout1 − Bout3	−3.33	(-11.20,4.54)	0.581
		Bout2 − Bout3	−3.12	(-10.41,4.16)	0.573
	L : 5v5	Bout1 − Bout2	—		
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	L : 7v7	Bout1 − Bout2	0.14	(-5.37,5.65)	0.998
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
V_{Z5} (m)	S : 3v3	Bout1 − Bout2	0.00	(-1.34,1.34)	1.000
101 / 1004 Bouts with missing measurements.		Bout1 − Bout3	0.00	(-1.16,1.16)	1.000
		Bout2 − Bout3	0.00	(-1.37,1.37)	1.000
	S : 5v5	Bout1 − Bout2	−0.20	(-1.38,0.98)	0.917
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	S : 7v7	Bout1 − Bout2	—		
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	M : 3v3	Bout1 − Bout2	0.07	(-0.93,1.07)	0.985
		Bout1 − Bout3	0.14	(-0.99,1.27)	0.953
		Bout2 − Bout3	0.07	(-1.06,1.20)	0.988
	M : 5v5	Bout1 − Bout2	0.00	(-1.18,1.18)	1.000
		Bout1 − Bout3	−0.00	(-1.18,1.18)	1.000
		Bout2 − Bout3	−0.00	(-1.18,1.18)	1.000
	M : 7v7	Bout1 − Bout2	−0.00	(-1.32,1.32)	1.000
		Bout1 − Bout3	−0.00	(-1.32,1.32)	1.000
		Bout2 − Bout3	−0.00	(-1.32,1.32)	1.000
	L : 3v3	Bout1 − Bout2	4.83	(3.41,6.26)	<0.001
		Bout1 − Bout3	4.58	(3.16,6.01)	<0.001
		Bout2 − Bout3	−0.25	(-1.57,1.07)	0.897
	L : 5v5	Bout1 − Bout2	—		
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	L : 7v7	Bout1 − Bout2	−0.00	(-1.00,1.00)	1.000
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		

U15	Pitch * No.	Comparison	Estimate	95% Adj. C.I.	Adj. *p*-value
V_{Z1} (m)	S : 3v3	Bout1 − Bout2	−7.60	(-42.20,27.00)	0.864
101 / 1004 Bouts with missing measurements.		Bout1 − Bout3	−11.20	(-45.80,23.40)	0.728
		Bout2 − Bout3	−3.60	(-38.20,31.00)	0.968
	S : 5v5	Bout1 − Bout2	−7.00	(-31.46,17.46)	0.780
		Bout1 − Bout3	−5.70	(-30.16,18.76)	0.848
		Bout2 − Bout3	1.30	(-23.16,25.76)	0.991
	S : 7v7	Bout1 − Bout2	8.46	(-13.00,29.92)	0.624
		Bout1 − Bout3	21.67	(-0.23,43.57)	0.053
		Bout2 − Bout3	13.21	(-8.69,35.10)	0.333
	M : 3v3	Bout1 − Bout2	−17.50	(-49.08,14.08)	0.395
		Bout1 − Bout3	−5.83	(-37.42,25.75)	0.902
		Bout2 − Bout3	11.67	(-19.92,43.25)	0.661
	M : 5v5	Bout1 − Bout2	—		
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	M : 7v7	Bout1 − Bout2	−13.12	(-28.59,2.35)	0.115
		Bout1 − Bout3	−13.22	(-28.55,2.10)	0.107
		Bout2 − Bout3	−0.10	(-15.43,15.22)	1.000
	L : 3v3	Bout1 − Bout2	−12.10	(-45.23,21.03)	0.667
		Bout1 − Bout3	−23.10	(-56.23,10.03)	0.231
		Bout2 − Bout3	−11.00	(-45.60,23.60)	0.736
	L : 5v5	Bout1 − Bout2	−8.00	(-32.46,16.46)	0.723
		Bout1 − Bout3	−10.10	(-34.56,14.36)	0.596
		Bout2 − Bout3	−2.10	(-26.56,22.36)	0.978
	L : 7v7	Bout1 − Bout2	−5.08	(-26.53,16.38)	0.844
		Bout1 − Bout3	−5.69	(-27.15,15.76)	0.808
		Bout2 − Bout3	−0.62	(-22.07,20.84)	0.998
V_{Z2} (m)	S : 3v3	Bout1 − Bout2	22.60	(-52.41,97.61)	0.759
101 / 1004 Bouts with missing measurements.		Bout1 − Bout3	40.20	(-34.81,115.21)	0.419
		Bout2 − Bout3	17.60	(-57.41,92.61)	0.846
	S : 5v5	Bout1 − Bout2	8.90	(-44.14,61.94)	0.918
		Bout1 − Bout3	−3.80	(-56.84,49.24)	0.985
		Bout2 − Bout3	−12.70	(-65.74,40.34)	0.840
	S : 7v7	Bout1 − Bout2	−12.38	(-58.90,34.14)	0.806
		Bout1 − Bout3	7.51	(-39.97,54.99)	0.927
		Bout2 − Bout3	19.89	(-27.59,67.37)	0.587
	M : 3v3	Bout1 − Bout2	13.00	(-55.48,81.48)	0.896
		Bout1 − Bout3	78.17	(9.69,146.64)	0.020
		Bout2 − Bout3	65.17	(-3.31,133.64)	0.066
	M : 5v5	Bout1 − Bout2	—		
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	M : 7v7	Bout1 − Bout2	22.36	(-11.19,55.91)	0.261
		Bout1 − Bout3	6.44	(-26.78,39.66)	0.892

U15	Pitch * No.	Comparison	Estimate	95% Adj. C.I.	Adj. *p*-value
		Bout2 − Bout3	−15.92	(-49.14,17.30)	0.499
	L : 3v3	Bout1 − Bout2	30.23	(-41.58,102.05)	0.584
		Bout1 − Bout3	90.83	(19.02,162.65)	0.009
		Bout2 − Bout3	60.60	(-14.41,135.61)	0.140
	L : 5v5	Bout1 − Bout2	13.20	(-39.84,66.24)	0.829
		Bout1 − Bout3	34.30	(-18.74,87.34)	0.283
		Bout2 − Bout3	21.10	(-31.94,74.14)	0.619
	L : 7v7	Bout1 − Bout2	12.85	(-33.67,59.37)	0.793
		Bout1 − Bout3	18.77	(-27.75,65.29)	0.610
		Bout2 − Bout3	5.92	(-40.60,52.44)	0.952
V_{Z3} (m)	S : 3v3	Bout1 − Bout2	2.40	(-32.99,37.79)	0.986
101 / 1004 Bouts with missing measurements.		Bout1 − Bout3	18.80	(-16.59,54.19)	0.426
		Bout2 − Bout3	16.40	(-18.99,51.79)	0.522
	S : 5v5	Bout1 − Bout2	−4.50	(-29.53,20.53)	0.906
		Bout1 − Bout3	−9.60	(-34.63,15.43)	0.640
		Bout2 − Bout3	−5.10	(-30.13,19.93)	0.881
	S : 7v7	Bout1 − Bout2	8.31	(-13.64,30.26)	0.648
		Bout1 − Bout3	−2.70	(-25.10,19.70)	0.957
		Bout2 − Bout3	−11.01	(-33.41,11.40)	0.481
	M : 3v3	Bout1 − Bout2	−1.17	(-33.48,31.14)	0.996
		Bout1 − Bout3	16.50	(-15.81,48.81)	0.454
		Bout2 − Bout3	17.67	(-14.64,49.98)	0.405
	M : 5v5	Bout1 − Bout2	—		
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	M : 7v7	Bout1 − Bout2	6.72	(-9.11,22.55)	0.579
		Bout1 − Bout3	−21.35	(-37.03,-5.68)	0.004
		Bout2 − Bout3	−28.07	(-43.75,-12.40)	<0.001
	L : 3v3	Bout1 − Bout2	4.77	(-29.12,38.65)	0.942
		Bout1 − Bout3	−10.23	(-44.12,23.65)	0.758
		Bout2 − Bout3	−15.00	(-50.39,20.39)	0.580
	L : 5v5	Bout1 − Bout2	22.90	(-2.13,47.93)	0.081
		Bout1 − Bout3	23.80	(-1.23,48.83)	0.066
		Bout2 − Bout3	0.90	(-24.13,25.93)	0.996
	L : 7v7	Bout1 − Bout2	5.08	(-16.87,27.03)	0.850
		Bout1 − Bout3	5.85	(-16.10,27.80)	0.806
		Bout2 − Bout3	0.77	(-21.18,22.72)	0.996
V_{Z4} (m)	S : 3v3	Bout1 − Bout2	1.40	(-7.82,10.62)	0.932
101 / 1004 Bouts with missing measurements.		Bout1 − Bout3	2.20	(-7.02,11.42)	0.841
		Bout2 − Bout3	0.80	(-8.42,10.02)	0.977
	S : 5v5	Bout1 − Bout2	−0.90	(-7.42,5.62)	0.944
		Bout1 − Bout3	0.20	(-6.32,6.72)	0.997
		Bout2 − Bout3	1.10	(-5.42,7.62)	0.917
	S : 7v7	Bout1 − Bout2	0.85	(-4.87,6.56)	0.936
		Bout1 − Bout3	0.98	(-4.85,6.81)	0.918

U15	Pitch * No.	Comparison	Estimate	95% Adj. C.I.	Adj. *p*-value
		Bout2 − Bout3	0.13	(-5.70,5.97)	0.998
	M : 3v3	Bout1 − Bout2	1.83	(-6.58,10.25)	0.866
		Bout1 − Bout3	−0.83	(-9.25,7.58)	0.971
		Bout2 − Bout3	−2.67	(-11.08,5.75)	0.737
	M : 5v5	Bout1 − Bout2	—		
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	M : 7v7	Bout1 − Bout2	−1.88	(-6.00,2.24)	0.532
		Bout1 − Bout3	−1.09	(-5.17,2.99)	0.805
		Bout2 − Bout3	0.79	(-3.29,4.87)	0.893
	L : 3v3	Bout1 − Bout2	8.27	(-0.56,17.09)	0.072
		Bout1 − Bout3	1.67	(-7.16,10.49)	0.897
		Bout2 − Bout3	−6.60	(-15.82,2.62)	0.213
	L : 5v5	Bout1 − Bout2	−0.20	(-6.72,6.32)	0.997
		Bout1 − Bout3	3.40	(-3.12,9.92)	0.439
		Bout2 − Bout3	3.60	(-2.92,10.12)	0.397
	L : 7v7	Bout1 − Bout2	2.08	(-3.64,7.79)	0.670
		Bout1 − Bout3	0.23	(-5.49,5.95)	0.995
		Bout2 − Bout3	−1.85	(-7.56,3.87)	0.729
V_{Z5} (m)	S : 3v3	Bout1 − Bout2	0.00	(-1.67,1.67)	1.000
101 / 1004 Bouts with missing measurements.		Bout1 − Bout3	0.00	(-1.67,1.67)	1.000
		Bout2 − Bout3	−0.00	(-1.67,1.67)	1.000
	S : 5v5	Bout1 − Bout2	0.00	(-1.18,1.18)	1.000
		Bout1 − Bout3	0.00	(-1.18,1.18)	1.000
		Bout2 − Bout3	−0.00	(-1.18,1.18)	1.000
	S : 7v7	Bout1 − Bout2	−0.15	(-1.19,0.88)	0.935
		Bout1 − Bout3	0.00	(-1.06,1.06)	1.000
		Bout2 − Bout3	0.15	(-0.90,1.21)	0.938
	M : 3v3	Bout1 − Bout2	0.00	(-1.53,1.53)	1.000
		Bout1 − Bout3	−0.00	(-1.53,1.53)	1.000
		Bout2 − Bout3	−0.00	(-1.53,1.53)	1.000
	M : 5v5	Bout1 − Bout2	—		
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	M : 7v7	Bout1 − Bout2	0.12	(-0.63,0.87)	0.925
		Bout1 − Bout3	−0.11	(-0.85,0.63)	0.938
		Bout2 − Bout3	−0.23	(-0.97,0.51)	0.751
	L : 3v3	Bout1 − Bout2	3.00	(1.40,4.60)	<0.001
		Bout1 − Bout3	2.80	(1.20,4.40)	<0.001
		Bout2 − Bout3	−0.20	(-1.87,1.47)	0.957
	L : 5v5	Bout1 − Bout2	0.20	(-0.98,1.38)	0.917
		Bout1 − Bout3	0.30	(-0.88,1.48)	0.822
		Bout2 − Bout3	0.10	(-1.08,1.28)	0.978
	L : 7v7	Bout1 − Bout2	0.15	(-0.88,1.19)	0.935
		Bout1 − Bout3	−0.31	(-1.34,0.73)	0.765
		Bout2 − Bout3	−0.46	(-1.50,0.58)	0.549

U16	Pitch * No.	Comparison	Estimate	95% Adj. C.I.	Adj. *p*-value
V_{Z1} (m)	S : 3v3	Bout1 − Bout2	−8.00	(-62.70,46.70)	0.937
101 / 1004 Bouts with missing measurements.		Bout1 − Bout3	−7.00	(-61.70,47.70)	0.951
		Bout2 − Bout3	1.00	(-53.70,55.70)	0.999
	S : 5v5	Bout1 − Bout2	5.00	(-72.36,82.36)	0.987
		Bout1 − Bout3	8.00	(-69.36,85.36)	0.968
		Bout2 − Bout3	3.00	(-74.36,80.36)	0.995
	S : 7v7	Bout1 − Bout2	−2.00	(-46.67,42.67)	0.994
		Bout1 − Bout3	−16.33	(-61.00,28.33)	0.667
		Bout2 − Bout3	−14.33	(-59.00,30.33)	0.732
	M : 3v3	Bout1 − Bout2	0.68	(-25.90,27.26)	0.998
		Bout1 − Bout3	−8.11	(-33.90,17.68)	0.741
		Bout2 − Bout3	−8.79	(-35.37,17.79)	0.718
	M : 5v5	Bout1 − Bout2	−7.00	(-84.36,70.36)	0.975
		Bout1 − Bout3	−11.00	(-88.36,66.36)	0.940
		Bout2 − Bout3	−4.00	(-81.36,73.36)	0.992
	M : 7v7	Bout1 − Bout2	0.67	(-44.00,45.33)	0.999
		Bout1 − Bout3	−5.00	(-49.67,39.67)	0.963
		Bout2 − Bout3	−5.67	(-50.33,39.00)	0.952
	L : 3v3	Bout1 − Bout2	−7.17	(-38.75,24.42)	0.855
		Bout1 − Bout3	−5.83	(-37.42,25.75)	0.902
		Bout2 − Bout3	1.33	(-30.25,32.92)	0.995
	L : 5v5	Bout1 − Bout2	—		
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	L : 7v7	Bout1 − Bout2	−6.00	(-44.68,32.68)	0.930
		Bout1 − Bout3	−19.50	(-58.18,19.18)	0.463
		Bout2 − Bout3	−13.50	(-52.18,25.18)	0.691
V_{Z2} (m)	S : 3v3	Bout1 − Bout2	27.00	(-91.60,145.60)	0.854
101 / 1004 Bouts with missing measurements.		Bout1 − Bout3	39.00	(-79.60,157.60)	0.720
		Bout2 − Bout3	12.00	(-106.60,130.60)	0.969
	S : 5v5	Bout1 − Bout2	9.00	(-158.73,176.73)	0.991
		Bout1 − Bout3	4.00	(-163.73,171.73)	0.998
		Bout2 − Bout3	−5.00	(-172.73,162.73)	0.997
	S : 7v7	Bout1 − Bout2	18.00	(-78.84,114.84)	0.900
		Bout1 − Bout3	48.00	(-48.84,144.84)	0.475
		Bout2 − Bout3	30.00	(-66.84,126.84)	0.747
	M : 3v3	Bout1 − Bout2	17.92	(-39.71,75.55)	0.746
		Bout1 − Bout3	6.11	(-49.80,62.02)	0.964
		Bout2 − Bout3	−11.81	(-69.44,45.83)	0.880
	M : 5v5	Bout1 − Bout2	17.00	(-150.73,184.73)	0.969
		Bout1 − Bout3	34.00	(-133.73,201.73)	0.883
		Bout2 − Bout3	17.00	(-150.73,184.73)	0.969
	M : 7v7	Bout1 − Bout2	22.33	(-74.51,119.17)	0.851
		Bout1 − Bout3	31.33	(-65.51,128.17)	0.728
		Bout2 − Bout3	9.00	(-87.84,105.84)	0.974

U16	Pitch * No.	Comparison	Estimate	95% Adj. C.I.	Adj. *p*-value
	L : 3v3	Bout1 − Bout2	13.50	(-54.98,81.98)	0.889
		Bout1 − Bout3	7.50	(-60.98,75.98)	0.964
		Bout2 − Bout3	−6.00	(-74.48,62.48)	0.977
	L : 5v5	Bout1 − Bout2	—		
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	L : 7v7	Bout1 − Bout2	13.00	(-70.87,96.87)	0.930
		Bout1 − Bout3	49.25	(-34.62,133.12)	0.352
		Bout2 − Bout3	36.25	(-47.62,120.12)	0.568
V_{Z3} (m)	S : 3v3	Bout1 − Bout2	24.00	(-31.96,79.96)	0.573
101 / 1004 Bouts with missing measurements.		Bout1 − Bout3	−16.50	(-72.46,39.46)	0.768
		Bout2 − Bout3	−40.50	(-96.46,15.46)	0.206
	S : 5v5	Bout1 − Bout2	−60.00	(-139.14,19.14)	0.177
		Bout1 − Bout3	−17.00	(-96.14,62.14)	0.869
		Bout2 − Bout3	43.00	(-36.14,122.14)	0.409
	S : 7v7	Bout1 − Bout2	0.33	(-45.36,46.02)	1.000
		Bout1 − Bout3	6.67	(-39.02,52.36)	0.937
		Bout2 − Bout3	6.33	(-39.36,52.02)	0.943
	M : 3v3	Bout1 − Bout2	−18.89	(-46.08,8.30)	0.233
		Bout1 − Bout3	30.44	(4.06,56.82)	0.019
		Bout2 − Bout3	49.33	(22.14,76.53)	<0.001
	M : 5v5	Bout1 − Bout2	−1.00	(-80.14,78.14)	1.000
		Bout1 − Bout3	3.00	(-76.14,82.14)	0.996
		Bout2 − Bout3	4.00	(-75.14,83.14)	0.992
	M : 7v7	Bout1 − Bout2	8.33	(-37.36,54.02)	0.904
		Bout1 − Bout3	−5.33	(-51.02,40.36)	0.959
		Bout2 − Bout3	−13.67	(-59.36,32.02)	0.762
	L : 3v3	Bout1 − Bout2	−23.00	(-55.31,9.31)	0.217
		Bout1 − Bout3	−12.50	(-44.81,19.81)	0.635
		Bout2 − Bout3	10.50	(-21.81,42.81)	0.726
	L : 5v5	Bout1 − Bout2	—		
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	L : 7v7	Bout1 − Bout2	−13.25	(-52.82,26.32)	0.712
		Bout1 − Bout3	−10.25	(-49.82,29.32)	0.816
		Bout2 − Bout3	3.00	(-36.57,42.57)	0.983
V_{Z4} (m)	S : 3v3	Bout1 − Bout2	−0.00	(-14.57,14.57)	1.000
101 / 1004 Bouts with missing measurements.		Bout1 − Bout3	−1.00	(-15.57,13.57)	0.986
		Bout2 − Bout3	−1.00	(-15.57,13.57)	0.986
	S : 5v5	Bout1 − Bout2	−0.00	(-20.61,20.61)	1.000
		Bout1 − Bout3	−0.00	(-20.61,20.61)	1.000
		Bout2 − Bout3	−0.00	(-20.61,20.61)	1.000
	S : 7v7	Bout1 − Bout2	0.00	(-11.90,11.90)	1.000
		Bout1 − Bout3	−0.00	(-11.90,11.90)	1.000
		Bout2 − Bout3	−0.00	(-11.90,11.90)	1.000

U16	Pitch * No.	Comparison	Estimate	95% Adj. C.I.	Adj. *p*-value
	M : 3v3	Bout1 − Bout2	−1.10	(-8.18,5.98)	0.930
		Bout1 − Bout3	4.56	(-2.31,11.43)	0.265
		Bout2 − Bout3	5.65	(-1.43,12.73)	0.147
	M : 5v5	Bout1 − Bout2	0.00	(-20.61,20.61)	1.000
		Bout1 − Bout3	−0.00	(-20.61,20.61)	1.000
		Bout2 − Bout3	−0.00	(-20.61,20.61)	1.000
	M : 7v7	Bout1 − Bout2	2.33	(-9.57,14.23)	0.890
		Bout1 − Bout3	2.33	(-9.57,14.23)	0.890
		Bout2 − Bout3	−0.00	(-11.90,11.90)	1.000
	L : 3v3	Bout1 − Bout2	4.00	(-4.41,12.41)	0.504
		Bout1 − Bout3	1.83	(-6.58,10.25)	0.866
		Bout2 − Bout3	−2.17	(-10.58,6.25)	0.818
	L : 5v5	Bout1 − Bout2	—		
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	L : 7v7	Bout1 − Bout2	−2.00	(-12.31,8.31)	0.892
		Bout1 − Bout3	−0.00	(-10.31,10.31)	1.000
		Bout2 − Bout3	2.00	(-8.31,12.31)	0.892
V_{Z5} (m)	S : 3v3	Bout1 − Bout2	0.00	(-2.64,2.64)	1.000
101 / 1004 Bouts with missing measurements.		Bout1 − Bout3	−0.00	(-2.64,2.64)	1.000
		Bout2 − Bout3	−0.00	(-2.64,2.64)	1.000
	S : 5v5	Bout1 − Bout2	0.00	(-3.74,3.74)	1.000
		Bout1 − Bout3	0.00	(-3.74,3.74)	1.000
		Bout2 − Bout3	−0.00	(-3.74,3.74)	1.000
	S : 7v7	Bout1 − Bout2	0.00	(-2.16,2.16)	1.000
		Bout1 − Bout3	0.00	(-2.16,2.16)	1.000
		Bout2 − Bout3	−0.00	(-2.16,2.16)	1.000
	M : 3v3	Bout1 − Bout2	0.11	(-1.17,1.40)	0.978
		Bout1 − Bout3	0.11	(-1.14,1.36)	0.976
		Bout2 − Bout3	−0.00	(-1.28,1.28)	1.000
	M : 5v5	Bout1 − Bout2	0.00	(-3.74,3.74)	1.000
		Bout1 − Bout3	0.00	(-3.74,3.74)	1.000
		Bout2 − Bout3	0.00	(-3.74,3.74)	1.000
	M : 7v7	Bout1 − Bout2	−0.00	(-2.16,2.16)	1.000
		Bout1 − Bout3	0.00	(-2.16,2.16)	1.000
		Bout2 − Bout3	0.00	(-2.16,2.16)	1.000
	L : 3v3	Bout1 − Bout2	−0.17	(-1.69,1.36)	0.964
		Bout1 − Bout3	0.17	(-1.36,1.69)	0.964
		Bout2 − Bout3	0.33	(-1.19,1.86)	0.865
	L : 5v5	Bout1 − Bout2	—		
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	L : 7v7	Bout1 − Bout2	−0.50	(-2.37,1.37)	0.805
		Bout1 − Bout3	0.00	(-1.87,1.87)	1.000
		Bout2 − Bout3	0.50	(-1.37,2.37)	0.805

U18	Pitch * No.	Comparison	Estimate	95% Adj. C.I.	Adj. *p*-value
V_{Z1} (m)	S : 3v3	Bout1 − Bout2	−1.09	(-17.22,15.04)	0.986
101 / 1004 Bouts with missing measurements.		Bout1 − Bout3	−1.87	(-18.00,14.26)	0.960
		Bout2 − Bout3	−0.78	(-16.91,15.35)	0.993
	S : 5v5	Bout1 − Bout2	−8.00	(-37.24,21.24)	0.797
		Bout1 − Bout3	5.00	(-24.24,34.24)	0.915
		Bout2 − Bout3	13.00	(-16.24,42.24)	0.549
	S : 7v7	Bout1 − Bout2	−2.00	(-26.46,22.46)	0.980
		Bout1 − Bout3	2.80	(-21.66,27.26)	0.961
		Bout2 − Bout3	4.80	(-19.66,29.26)	0.890
	M : 3v3	Bout1 − Bout2	−2.91	(-22.57,16.75)	0.936
		Bout1 − Bout3	−11.67	(-31.64,8.31)	0.356
		Bout2 − Bout3	−8.76	(-28.42,10.90)	0.548
	M : 5v5	Bout1 − Bout2	−36.20	(-70.80,-1.60)	0.038
		Bout1 − Bout3	−9.80	(-42.93,23.33)	0.767
		Bout2 − Bout3	26.40	(-6.73,59.53)	0.148
	M : 7v7	Bout1 − Bout2	0.30	(-24.16,24.76)	1.000
		Bout1 − Bout3	1.90	(-22.56,26.36)	0.982
		Bout2 − Bout3	1.60	(-22.86,26.06)	0.987
	L : 3v3	Bout1 − Bout2	−4.00	(-23.66,15.66)	0.882
		Bout1 − Bout3	2.73	(-16.93,22.39)	0.943
		Bout2 − Bout3	6.73	(-13.24,26.71)	0.708
	L : 5v5	Bout1 − Bout2	−0.53	(-19.03,17.97)	0.998
		Bout1 − Bout3	0.03	(-18.47,18.53)	1.000
		Bout2 − Bout3	0.56	(-17.68,18.79)	0.997
	L : 7v7	Bout1 − Bout2	−20.00	(-37.75,-2.25)	0.023
		Bout1 − Bout3	−17.14	(-35.13,0.85)	0.066
		Bout2 − Bout3	2.86	(-15.13,20.85)	0.926
V_{Z2} (m)	S : 3v3	Bout1 − Bout2	2.70	(-32.28,37.67)	0.982
101 / 1004 Bouts with missing measurements.		Bout1 − Bout3	27.22	(-7.76,62.19)	0.161
		Bout2 − Bout3	24.52	(-10.45,59.50)	0.227
	S : 5v5	Bout1 − Bout2	−42.00	(-105.40,21.40)	0.266
		Bout1 − Bout3	−16.43	(-79.82,46.97)	0.816
		Bout2 − Bout3	25.57	(-37.82,88.97)	0.611
	S : 7v7	Bout1 − Bout2	18.30	(-34.74,71.34)	0.697
		Bout1 − Bout3	−14.40	(-67.44,38.64)	0.799
		Bout2 − Bout3	−32.70	(-85.74,20.34)	0.317
	M : 3v3	Bout1 − Bout2	4.03	(-38.59,46.66)	0.973
		Bout1 − Bout3	33.47	(-9.84,76.77)	0.165
		Bout2 − Bout3	29.43	(-13.19,72.06)	0.237
	M : 5v5	Bout1 − Bout2	38.20	(-36.81,113.21)	0.456
		Bout1 − Bout3	−1.00	(-72.82,70.82)	0.999
		Bout2 − Bout3	−39.20	(-111.02,32.62)	0.406

U18	Pitch * No.	Comparison	Estimate	95% Adj. C.I.	Adj. *p*-value
	M : 7v7	Bout1 − Bout2	29.60	(-23.44,82.64)	0.390
		Bout1 − Bout3	50.60	(-2.44,103.64)	0.065
		Bout2 − Bout3	21.00	(-32.04,74.04)	0.622
	L : 3v3	Bout1 − Bout2	32.84	(-9.78,75.47)	0.167
		Bout1 − Bout3	5.11	(-37.52,47.73)	0.957
		Bout2 − Bout3	−27.73	(-71.04,15.57)	0.290
	L : 5v5	Bout1 − Bout2	16.54	(-23.58,56.65)	0.597
		Bout1 − Bout3	46.59	(6.48,86.70)	0.018
		Bout2 − Bout3	30.06	(-9.48,69.59)	0.175
	L : 7v7	Bout1 − Bout2	31.58	(-6.90,70.06)	0.132
		Bout1 − Bout3	26.19	(-12.82,65.20)	0.257
		Bout2 − Bout3	−5.39	(-44.40,33.62)	0.944
V_{Z3} (m)	S : 3v3	Bout1 − Bout2	−0.30	(-16.81,16.20)	0.999
101 / 1004 Bouts with missing measurements.		Bout1 − Bout3	−2.83	(-19.33,13.68)	0.915
		Bout2 − Bout3	−2.52	(-19.02,13.98)	0.932
	S : 5v5	Bout1 − Bout2	−2.86	(-32.77,27.05)	0.973
		Bout1 − Bout3	−8.43	(-38.34,21.48)	0.786
		Bout2 − Bout3	−5.57	(-35.48,24.34)	0.900
	S : 7v7	Bout1 − Bout2	3.20	(-21.83,28.23)	0.952
		Bout1 − Bout3	4.30	(-20.73,29.33)	0.914
		Bout2 − Bout3	1.10	(-23.93,26.13)	0.994
	M : 3v3	Bout1 − Bout2	4.32	(-15.80,24.43)	0.869
		Bout1 − Bout3	4.20	(-16.23,24.63)	0.880
		Bout2 − Bout3	−0.12	(-20.23,20.00)	1.000
	M : 5v5	Bout1 − Bout2	12.40	(-22.99,47.79)	0.689
		Bout1 − Bout3	10.20	(-23.69,44.09)	0.760
		Bout2 − Bout3	−2.20	(-36.09,31.69)	0.987
	M : 7v7	Bout1 − Bout2	−15.50	(-40.53,9.53)	0.314
		Bout1 − Bout3	−5.20	(-30.23,19.83)	0.877
		Bout2 − Bout3	10.30	(-14.73,35.33)	0.598
	L : 3v3	Bout1 − Bout2	8.47	(-11.64,28.59)	0.584
		Bout1 − Bout3	4.54	(-15.57,24.65)	0.857
		Bout2 − Bout3	−3.93	(-24.37,16.50)	0.894
	L : 5v5	Bout1 − Bout2	−0.98	(-19.90,17.95)	0.992
		Bout1 − Bout3	−8.87	(-27.79,10.06)	0.514
		Bout2 − Bout3	−7.89	(-26.54,10.76)	0.581
	L : 7v7	Bout1 − Bout2	18.42	(0.27,36.58)	0.046
		Bout1 − Bout3	21.66	(3.25,40.06)	0.016
		Bout2 − Bout3	3.24	(-15.17,21.64)	0.910
V_{Z4} (m)	S : 3v3	Bout1 − Bout2	−1.00	(-5.30,3.30)	0.848
101 / 1004 Bouts with missing measurements.		Bout1 − Bout3	−0.04	(-4.34,4.25)	1.000
		Bout2 − Bout3	0.96	(-3.34,5.25)	0.860
	S : 5v5	Bout1 − Bout2	−0.14	(-7.93,7.65)	0.999
		Bout1 − Bout3	0.00	(-7.79,7.79)	1.000
		Bout2 − Bout3	0.14	(-7.65,7.93)	0.999

U18	Pitch * No.	Comparison	Estimate	95% Adj. C.I.	Adj. *p*-value
	S : 7v7	Bout1 − Bout2	−0.00	(-6.52,6.52)	1.000
		Bout1 − Bout3	−0.00	(-6.52,6.52)	1.000
		Bout2 − Bout3	0.00	(-6.52,6.52)	1.000
	M : 3v3	Bout1 − Bout2	−0.99	(-6.23,4.25)	0.898
		Bout1 − Bout3	−1.27	(-6.59,4.05)	0.842
		Bout2 − Bout3	−0.28	(-5.52,4.96)	0.991
	M : 5v5	Bout1 − Bout2	6.20	(-3.02,15.42)	0.255
		Bout1 − Bout3	6.87	(-1.96,15.69)	0.161
		Bout2 − Bout3	0.67	(-8.16,9.49)	0.983
	M : 7v7	Bout1 − Bout2	−6.30	(-12.82,0.22)	0.061
		Bout1 − Bout3	−4.70	(-11.22,1.82)	0.208
		Bout2 − Bout3	1.60	(-4.92,8.12)	0.833
	L : 3v3	Bout1 − Bout2	1.73	(-3.51,6.97)	0.718
		Bout1 − Bout3	0.60	(-4.64,5.83)	0.961
		Bout2 − Bout3	−1.13	(-6.45,4.19)	0.871
	L : 5v5	Bout1 − Bout2	−1.18	(-6.11,3.75)	0.841
		Bout1 − Bout3	−6.07	(-10.99,-1.14)	0.011
		Bout2 − Bout3	−4.89	(-9.75,-0.03)	0.048
	L : 7v7	Bout1 − Bout2	2.32	(-2.41,7.04)	0.484
		Bout1 − Bout3	1.17	(-3.63,5.96)	0.835
		Bout2 − Bout3	−1.15	(-5.94,3.64)	0.840
V_{Z5} (m)	S : 3v3	Bout1 − Bout2	−0.09	(-0.87,0.69)	0.963
101 / 1004 Bouts with missing measurements.		Bout1 − Bout3	0.04	(-0.74,0.82)	0.991
		Bout2 − Bout3	0.13	(-0.65,0.91)	0.918
	S : 5v5	Bout1 − Bout2	−0.00	(-1.41,1.41)	1.000
		Bout1 − Bout3	−0.00	(-1.41,1.41)	1.000
		Bout2 − Bout3	−0.00	(-1.41,1.41)	1.000
	S : 7v7	Bout1 − Bout2	0.00	(-1.18,1.18)	1.000
		Bout1 − Bout3	0.00	(-1.18,1.18)	1.000
		Bout2 − Bout3	−0.00	(-1.18,1.18)	1.000
	M : 3v3	Bout1 − Bout2	0.47	(-0.48,1.42)	0.482
		Bout1 − Bout3	0.47	(-0.50,1.43)	0.493
		Bout2 − Bout3	0.00	(-0.95,0.95)	1.000
	M : 5v5	Bout1 − Bout2	−0.00	(-1.67,1.67)	1.000
		Bout1 − Bout3	−0.00	(-1.60,1.60)	1.000
		Bout2 − Bout3	−0.00	(-1.60,1.60)	1.000
	M : 7v7	Bout1 − Bout2	0.40	(-0.78,1.58)	0.707
		Bout1 − Bout3	0.60	(-0.58,1.78)	0.458
		Bout2 − Bout3	0.20	(-0.98,1.38)	0.917
	L : 3v3	Bout1 − Bout2	−0.00	(-0.95,0.95)	1.000
		Bout1 − Bout3	−0.13	(-1.08,0.82)	0.942
		Bout2 − Bout3	−0.13	(-1.10,0.83)	0.944
	L : 5v5	Bout1 − Bout2	−0.11	(-1.01,0.78)	0.954
		Bout1 − Bout3	−0.11	(-1.01,0.78)	0.954
		Bout2 − Bout3	−0.00	(-0.88,0.88)	1.000

U18	Pitch * No.	Comparison	Estimate	95% Adj. C.I.	Adj. *p*-value
	L : 7v7	Bout1 − Bout2	0.16	(-0.70,1.02)	0.902
		Bout1 − Bout3	0.16	(-0.71,1.03)	0.905
		Bout2 − Bout3	−0.00	(-0.87,0.87)	1.000

Appendix 16: Youth SSG formats bout differences – Heart rate zones (imputed values R)

Statistically significantly different (*p*≤ *0.05)*
Trend to significancy (*p*= *0.05-0.1)*

YOUTH	Pitch * No.	Comparison	Estimate	95% Adj. C.I.	Adj. *p*-value
HR_{Z1} (min)	S : 3v3	Bout1 − Bout2	0.18	(-0.07,0.43)	0.222
166 out of 1004 Bouts had missing measurements.		Bout1 − Bout3	0.05	(-0.20,0.30)	0.884
		Bout2 − Bout3	−0.13	(-0.38,0.12)	0.455
	S : 5v5	Bout1 − Bout2	0.03	(-0.26,0.33)	0.963
		Bout1 − Bout3	0.05	(-0.28,0.38)	0.928
		Bout2 − Bout3	0.02	(-0.31,0.35)	0.990
	S : 7v7	Bout1 − Bout2	0.23	(-0.08,0.55)	0.190
		Bout1 − Bout3	0.31	(-0.01,0.63)	0.058
		Bout2 − Bout3	0.08	(-0.24,0.40)	0.841
	M : 3v3	Bout1 − Bout2	0.07	(-0.17,0.31)	0.787
		Bout1 − Bout3	0.09	(-0.16,0.34)	0.651
		Bout2 − Bout3	0.03	(-0.22,0.27)	0.967
	M : 5v5	Bout1 − Bout2	0.12	(-0.29,0.52)	0.770
		Bout1 − Bout3	0.08	(-0.32,0.48)	0.875
		Bout2 − Bout3	−0.04	(-0.43,0.36)	0.976
	M : 7v7	Bout1 − Bout2	0.16	(-0.07,0.39)	0.216
		Bout1 − Bout3	0.18	(-0.05,0.41)	0.158
		Bout2 − Bout3	0.02	(-0.21,0.25)	0.983
	L : 3v3	Bout1 − Bout2	0.17	(-0.09,0.44)	0.278
		Bout1 − Bout3	0.20	(-0.06,0.47)	0.168
		Bout2 − Bout3	0.03	(-0.24,0.30)	0.960
	L : 5v5	Bout1 − Bout2	0.30	(-0.00,0.60)	0.053
		Bout1 − Bout3	0.33	(0.03,0.63)	0.030
		Bout2 − Bout3	0.03	(-0.26,0.32)	0.970
	L : 7v7	Bout1 − Bout2	0.18	(-0.04,0.40)	0.143
		Bout1 − Bout3	0.16	(-0.09,0.40)	0.284
		Bout2 − Bout3	−0.02	(-0.26,0.22)	0.972
HR_{Z2} (min)	S : 3v3	Bout1 − Bout2	0.20	(-0.12,0.53)	0.312
166 out of 1004 Bouts had missing measurements.		Bout1 − Bout3	0.15	(-0.16,0.47)	0.494
		Bout2 − Bout3	−0.05	(-0.38,0.28)	0.932
	S : 5v5	Bout1 − Bout2	−0.02	(-0.41,0.36)	0.990
		Bout1 − Bout3	0.11	(-0.32,0.54)	0.818
		Bout2 − Bout3	0.13	(-0.29,0.55)	0.741
	S : 7v7	Bout1 − Bout2	0.10	(-0.30,0.51)	0.820
		Bout1 − Bout3	0.15	(-0.26,0.56)	0.661
		Bout2 − Bout3	0.05	(-0.36,0.46)	0.960
	M : 3v3	Bout1 − Bout2	0.07	(-0.24,0.39)	0.841
		Bout1 − Bout3	0.11	(-0.21,0.44)	0.688
		Bout2 − Bout3	0.04	(-0.28,0.36)	0.956

YOUTH	Pitch * No.	Comparison	Estimate	95% Adj. C.I.	Adj. *p*-value
	M : 5v5	Bout1 − Bout2	0.09	(-0.43,0.62)	0.906
		Bout1 − Bout3	0.09	(-0.43,0.60)	0.917
		Bout2 − Bout3	−0.01	(-0.52,0.51)	0.999
	M : 7v7	Bout1 − Bout2	0.11	(-0.18,0.41)	0.635
		Bout1 − Bout3	0.29	(-0.01,0.59)	0.059
		Bout2 − Bout3	0.18	(-0.12,0.47)	0.349
	L : 3v3	Bout1 − Bout2	0.14	(-0.21,0.48)	0.620
		Bout1 − Bout3	0.10	(-0.24,0.45)	0.759
		Bout2 − Bout3	−0.03	(-0.38,0.31)	0.973
	L : 5v5	Bout1 − Bout2	0.07	(-0.32,0.46)	0.911
		Bout1 − Bout3	0.07	(-0.31,0.46)	0.893
		Bout2 − Bout3	0.01	(-0.37,0.38)	0.999
	L : 7v7	Bout1 − Bout2	0.23	(-0.05,0.52)	0.139
		Bout1 − Bout3	0.30	(-0.01,0.61)	0.065
		Bout2 − Bout3	0.06	(-0.24,0.37)	0.874
HR_{Z3} (min)	S : 3v3	Bout1 − Bout2	−0.16	(-0.62,0.29)	0.671
166 out of 1004 Bouts had missing measurements.		Bout1 − Bout3	−0.14	(-0.58,0.30)	0.745
		Bout2 − Bout3	0.03	(-0.43,0.48)	0.989
	S : 5v5	Bout1 − Bout2	0.01	(-0.53,0.54)	0.999
		Bout1 − Bout3	0.08	(-0.51,0.68)	0.944
		Bout2 − Bout3	0.07	(-0.51,0.66)	0.954
	S : 7v7	Bout1 − Bout2	−0.01	(-0.58,0.56)	0.999
		Bout1 − Bout3	−0.01	(-0.59,0.56)	0.999
		Bout2 − Bout3	0.00	(-0.57,0.57)	1.000
	M : 3v3	Bout1 − Bout2	0.01	(-0.43,0.44)	0.999
		Bout1 − Bout3	−0.13	(-0.58,0.32)	0.767
		Bout2 − Bout3	−0.14	(-0.58,0.31)	0.747
	M : 5v5	Bout1 − Bout2	−0.22	(-0.95,0.51)	0.762
		Bout1 − Bout3	−0.46	(-1.18,0.26)	0.287
		Bout2 − Bout3	−0.24	(-0.96,0.47)	0.707
	M : 7v7	Bout1 − Bout2	−0.16	(-0.58,0.25)	0.626
		Bout1 − Bout3	−0.23	(-0.65,0.18)	0.385
		Bout2 − Bout3	−0.07	(-0.48,0.34)	0.914
	L : 3v3	Bout1 − Bout2	−0.05	(-0.52,0.43)	0.973
		Bout1 − Bout3	−0.29	(-0.76,0.19)	0.341
		Bout2 − Bout3	−0.24	(-0.72,0.24)	0.471
	L : 5v5	Bout1 − Bout2	0.19	(-0.35,0.73)	0.676
		Bout1 − Bout3	0.10	(-0.44,0.64)	0.908
		Bout2 − Bout3	−0.10	(-0.62,0.43)	0.899
	L : 7v7	Bout1 − Bout2	0.06	(-0.33,0.46)	0.923
		Bout1 − Bout3	0.10	(-0.33,0.54)	0.841
		Bout2 − Bout3	0.04	(-0.39,0.47)	0.975
HR_{Z4} (min)	S : 3v3	Bout1 − Bout2	0.45	(-0.10,1.00)	0.133
166 out of 1004 Bouts		Bout1 − Bout3	0.28	(-0.26,0.81)	0.447
		Bout2 − Bout3	−0.17	(-0.72,0.38)	0.738

YOUTH	Pitch * No.	Comparison	Estimate	95% Adj. C.I.	Adj. *p*-value
had missing measurements.	S : 5v5	Bout1 − Bout2	0.19	(-0.46,0.83)	0.778
		Bout1 − Bout3	0.24	(-0.48,0.96)	0.721
		Bout2 − Bout3	0.05	(-0.66,0.76)	0.985
	S : 7v7	Bout1 − Bout2	0.24	(-0.45,0.93)	0.687
		Bout1 − Bout3	0.22	(-0.48,0.91)	0.742
		Bout2 − Bout3	−0.02	(-0.72,0.67)	0.997
	M : 3v3	Bout1 − Bout2	0.22	(-0.30,0.75)	0.580
		Bout1 − Bout3	0.25	(-0.30,0.79)	0.536
		Bout2 − Bout3	0.02	(-0.51,0.56)	0.994
	M : 5v5	Bout1 − Bout2	0.09	(-0.79,0.97)	0.969
		Bout1 − Bout3	0.08	(-0.79,0.94)	0.975
		Bout2 − Bout3	−0.01	(-0.87,0.86)	1.000
	M : 7v7	Bout1 − Bout2	−0.05	(-0.55,0.45)	0.972
		Bout1 − Bout3	−0.02	(-0.52,0.48)	0.996
		Bout2 − Bout3	0.03	(-0.47,0.53)	0.990
	L : 3v3	Bout1 − Bout2	0.10	(-0.48,0.67)	0.919
		Bout1 − Bout3	0.10	(-0.48,0.68)	0.909
		Bout2 − Bout3	0.01	(-0.58,0.59)	1.000
	L : 5v5	Bout1 − Bout2	−0.02	(-0.68,0.63)	0.996
		Bout1 − Bout3	0.09	(-0.57,0.74)	0.949
		Bout2 − Bout3	0.11	(-0.52,0.74)	0.915
	L : 7v7	Bout1 − Bout2	−0.22	(-0.70,0.26)	0.535
		Bout1 − Bout3	−0.13	(-0.66,0.39)	0.819
		Bout2 − Bout3	0.09	(-0.43,0.60)	0.921
HR_{Z5} (min)	S : 3v3	Bout1 − Bout2	−0.61	(-1.15,-0.08)	0.021
166 out of 1004 Bouts had missing measurements.		Bout1 − Bout3	−0.24	(-0.76,0.28)	0.518
		Bout2 − Bout3	0.37	(-0.17,0.90)	0.239
	S : 5v5	Bout1 − Bout2	−0.30	(-0.93,0.33)	0.496
		Bout1 − Bout3	−0.48	(-1.18,0.22)	0.245
		Bout2 − Bout3	−0.18	(-0.87,0.51)	0.821
	S : 7v7	Bout1 − Bout2	−0.44	(-1.11,0.23)	0.276
		Bout1 − Bout3	−0.45	(-1.13,0.22)	0.258
		Bout2 − Bout3	−0.02	(-0.69,0.66)	0.998
	M : 3v3	Bout1 − Bout2	−0.38	(-0.89,0.13)	0.187
		Bout1 − Bout3	−0.25	(-0.78,0.28)	0.508
		Bout2 − Bout3	0.13	(-0.39,0.66)	0.828
	M : 5v5	Bout1 − Bout2	−0.27	(-1.13,0.59)	0.736
		Bout1 − Bout3	0.10	(-0.74,0.95)	0.957
		Bout2 − Bout3	0.37	(-0.47,1.22)	0.551
	M : 7v7	Bout1 − Bout2	−0.18	(-0.67,0.31)	0.656
		Bout1 − Bout3	−0.30	(-0.79,0.19)	0.323
		Bout2 − Bout3	−0.12	(-0.60,0.37)	0.837
	L : 3v3	Bout1 − Bout2	−0.43	(-1.00,0.13)	0.168
		Bout1 − Bout3	−0.26	(-0.83,0.30)	0.519
		Bout2 − Bout3	0.17	(-0.40,0.74)	0.760

YOUTH	Pitch * No.	Comparison	Estimate	95% Adj. C.I.	Adj. *p*-value
	L : 5v5	Bout1 − Bout2	−0.49	(-1.13,0.15)	0.166
		Bout1 − Bout3	−0.53	(-1.17,0.11)	0.124
		Bout2 − Bout3	−0.04	(-0.66,0.58)	0.988
	L : 7v7	Bout1 − Bout2	−0.33	(-0.80,0.14)	0.232
		Bout1 − Bout3	−0.45	(-0.96,0.06)	0.101
		Bout2 − Bout3	−0.12	(-0.62,0.39)	0.843

U14	Pitch * No.	Comparison	Estimate	95% Adj. C.I.	Adj. *p*-value
HR_{Z1} (min)	S : 3v3	Bout1 − Bout2	0.24	(-0.34,0.82)	0.590
166 / 1004 Bouts with missing measurements.		Bout1 − Bout3	−0.24	(-0.72,0.24)	0.469
		Bout2 − Bout3	−0.48	(-1.07,0.10)	0.131
	S : 5v5	Bout1 − Bout2	−0.09	(-0.58,0.41)	0.910
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	S : 7v7	Bout1 − Bout2	—		
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	M : 3v3	Bout1 − Bout2	0.11	(-0.31,0.53)	0.818
		Bout1 − Bout3	0.19	(-0.29,0.67)	0.616
		Bout2 − Bout3	0.08	(-0.39,0.56)	0.910
	M : 5v5	Bout1 − Bout2	0.21	(-0.32,0.73)	0.621
		Bout1 − Bout3	0.20	(-0.33,0.73)	0.644
		Bout2 − Bout3	−0.01	(-0.53,0.52)	0.999
	M : 7v7	Bout1 − Bout2	0.95	(0.42,1.48)	<0.001
		Bout1 − Bout3	0.88	(0.35,1.40)	<0.001
		Bout2 − Bout3	−0.07	(-0.60,0.45)	0.943
	L : 3v3	Bout1 − Bout2	0.30	(-0.28,0.89)	0.449
		Bout1 − Bout3	0.34	(-0.25,0.92)	0.362
		Bout2 − Bout3	0.04	(-0.52,0.60)	0.986
	L : 5v5	Bout1 − Bout2	—		
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	L : 7v7	Bout1 − Bout2	−0.03	(-0.48,0.42)	0.987
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
HR_{Z2} (min)	S : 3v3	Bout1 − Bout2	0.22	(-0.49,0.92)	0.757
166 / 1004 Bouts with missing measurements.		Bout1 − Bout3	0.27	(-0.32,0.87)	0.526
		Bout2 − Bout3	0.06	(-0.66,0.78)	0.980
	S : 5v5	Bout1 − Bout2	−0.06	(-0.68,0.55)	0.966
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	S : 7v7	Bout1 − Bout2	—		
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	M : 3v3	Bout1 − Bout2	−0.14	(-0.66,0.38)	0.798
		Bout1 − Bout3	0.52	(-0.08,1.11)	0.102

YOUTH	Pitch * No.	Comparison	Estimate	95% Adj. C.I.	Adj. *p*-value
		Bout2 − Bout3	0.66	(0.07,1.24)	0.022
	M : 5v5	Bout1 − Bout2	0.06	(-0.58,0.71)	0.970
		Bout1 − Bout3	0.02	(-0.63,0.67)	0.997
		Bout2 − Bout3	−0.05	(-0.69,0.60)	0.985
	M : 7v7	Bout1 − Bout2	0.47	(-0.18,1.11)	0.209
		Bout1 − Bout3	0.03	(-0.62,0.68)	0.994
		Bout2 − Bout3	−0.44	(-1.09,0.21)	0.253
	L : 3v3	Bout1 − Bout2	−0.00	(-0.72,0.72)	1.000
		Bout1 − Bout3	−0.11	(-0.83,0.62)	0.936
		Bout2 − Bout3	−0.10	(-0.80,0.59)	0.933
	L : 5v5	Bout1 − Bout2	—		
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	L : 7v7	Bout1 − Bout2	0.12	(-0.44,0.67)	0.870
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
HR_{Z3} (min)	S : 3v3	Bout1 − Bout2	−0.56	(-1.59,0.46)	0.400
166 / 1004 Bouts with missing measurements.		Bout1 − Bout3	−0.15	(-1.01,0.71)	0.909
		Bout2 − Bout3	0.41	(-0.63,1.45)	0.623
	S : 5v5	Bout1 − Bout2	0.28	(-0.60,1.16)	0.740
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	S : 7v7	Bout1 − Bout2	—		
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	M : 3v3	Bout1 − Bout2	−0.19	(-0.94,0.56)	0.827
		Bout1 − Bout3	0.23	(-0.63,1.08)	0.805
		Bout2 − Bout3	0.42	(-0.42,1.26)	0.477
	M : 5v5	Bout1 − Bout2	−0.01	(-0.94,0.93)	1.000
		Bout1 − Bout3	−0.50	(-1.44,0.43)	0.414
		Bout2 − Bout3	−0.50	(-1.43,0.44)	0.427
	M : 7v7	Bout1 − Bout2	−0.84	(-1.77,0.10)	0.091
		Bout1 − Bout3	−0.93	(-1.86,0.01)	0.052
		Bout2 − Bout3	−0.09	(-1.03,0.84)	0.971
	L : 3v3	Bout1 − Bout2	−0.38	(-1.42,0.66)	0.666
		Bout1 − Bout3	−0.79	(-1.83,0.25)	0.177
		Bout2 − Bout3	−0.41	(-1.41,0.59)	0.604
	L : 5v5	Bout1 − Bout2	—		
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	L : 7v7	Bout1 − Bout2	0.17	(-0.63,0.97)	0.867
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
HR_{Z4} (min)	S : 3v3	Bout1 − Bout2	0.32	(-0.92,1.56)	0.813
		Bout1 − Bout3	−0.11	(-1.15,0.93)	0.965

YOUTH	Pitch * No.	Comparison	Estimate	95% Adj. C.I.	Adj. *p*-value
166 / 1004 Bouts with missing measurements.		Bout2 − Bout3	−0.44	(-1.70,0.83)	0.697
	S : 5v5	Bout1 − Bout2	−0.13	(-1.20,0.94)	0.956
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	S : 7v7	Bout1 − Bout2	—		
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	M : 3v3	Bout1 − Bout2	0.48	(-0.43,1.39)	0.427
		Bout1 − Bout3	0.23	(-0.80,1.27)	0.855
		Bout2 − Bout3	−0.25	(-1.26,0.77)	0.838
	M : 5v5	Bout1 − Bout2	−0.15	(-1.28,0.98)	0.946
		Bout1 − Bout3	0.19	(-0.95,1.32)	0.922
		Bout2 − Bout3	0.34	(-0.79,1.47)	0.763
	M : 7v7	Bout1 − Bout2	−0.96	(-2.10,0.17)	0.112
		Bout1 − Bout3	−0.37	(-1.50,0.76)	0.719
		Bout2 − Bout3	0.59	(-0.54,1.72)	0.436
	L : 3v3	Bout1 − Bout2	−0.35	(-1.60,0.91)	0.795
		Bout1 − Bout3	−0.85	(-2.11,0.41)	0.252
		Bout2 − Bout3	−0.50	(-1.71,0.70)	0.589
	L : 5v5	Bout1 − Bout2	—		
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	L : 7v7	Bout1 − Bout2	−0.20	(-1.17,0.77)	0.882
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
HR_{Z5} (min)	S : 3v3	Bout1 − Bout2	0.06	(-1.15,1.27)	0.993
166 / 1004 Bouts with missing measurements.		Bout1 − Bout3	0.33	(-0.68,1.35)	0.717
		Bout2 − Bout3	0.27	(-0.95,1.50)	0.859
	S : 5v5	Bout1 − Bout2	−0.16	(-1.20,0.88)	0.928
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	S : 7v7	Bout1 − Bout2	—		
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	M : 3v3	Bout1 − Bout2	−0.25	(-1.13,0.63)	0.780
		Bout1 − Bout3	−0.85	(-1.86,0.15)	0.115
		Bout2 − Bout3	−0.60	(-1.59,0.39)	0.328
	M : 5v5	Bout1 − Bout2	−0.36	(-1.46,0.75)	0.728
		Bout1 − Bout3	−0.10	(-1.21,1.00)	0.973
		Bout2 − Bout3	0.25	(-0.85,1.35)	0.853
	M : 7v7	Bout1 − Bout2	−0.11	(-1.21,0.99)	0.970
		Bout1 − Bout3	−0.00	(-1.10,1.10)	1.000
		Bout2 − Bout3	0.11	(-0.99,1.21)	0.970
	L : 3v3	Bout1 − Bout2	−0.13	(-1.35,1.10)	0.967

YOUTH	Pitch * No.	Comparison	Estimate	95% Adj. C.I.	Adj. *p*-value
		Bout1 − Bout3	0.53	(-0.70,1.75)	0.569
		Bout2 − Bout3	0.66	(-0.52,1.83)	0.390
	L : 5v5	Bout1 − Bout2	—		
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	L : 7v7	Bout1 − Bout2	−0.22	(-1.16,0.73)	0.851
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		

U15	Pitch * No.	Comparison	Estimate	95% Adj. C.I.	Adj. *p*-value
HR_{Z1} (min)	S : 3v3	Bout1 − Bout2	0.13	(-0.62,0.87)	0.918
166 / 1004 Bouts with missing measurements.		Bout1 − Bout3	0.13	(-0.62,0.87)	0.918
		Bout2 − Bout3	−0.00	(-0.74,0.74)	1.000
	S : 5v5	Bout1 − Bout2	0.02	(-0.48,0.52)	0.997
		Bout1 − Bout3	0.05	(-0.44,0.55)	0.964
		Bout2 − Bout3	0.04	(-0.43,0.51)	0.980
	S : 7v7	Bout1 − Bout2	0.49	(0.02,0.96)	0.040
		Bout1 − Bout3	0.66	(0.17,1.14)	0.004
		Bout2 − Bout3	0.17	(-0.31,0.65)	0.686
	M : 3v3	Bout1 − Bout2	0.18	(-0.68,1.04)	0.878
		Bout1 − Bout3	0.18	(-0.68,1.04)	0.878
		Bout2 − Bout3	0.00	(-0.86,0.86)	1.000
	M : 5v5	Bout1 − Bout2	—		
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	M : 7v7	Bout1 − Bout2	−0.04	(-0.35,0.28)	0.960
		Bout1 − Bout3	0.02	(-0.30,0.34)	0.988
		Bout2 − Bout3	0.06	(-0.26,0.37)	0.907
	L : 3v3	Bout1 − Bout2	0.45	(-0.26,1.15)	0.297
		Bout1 − Bout3	0.45	(-0.26,1.15)	0.297
		Bout2 − Bout3	0.00	(-0.74,0.74)	1.000
	L : 5v5	Bout1 − Bout2	0.24	(-0.25,0.74)	0.484
		Bout1 − Bout3	0.31	(-0.18,0.81)	0.304
		Bout2 − Bout3	0.07	(-0.43,0.56)	0.943
	L : 7v7	Bout1 − Bout2	0.05	(-0.37,0.47)	0.958
		Bout1 − Bout3	0.02	(-0.40,0.44)	0.994
		Bout2 − Bout3	−0.03	(-0.44,0.38)	0.983
HR_{Z2} (min)	S : 3v3	Bout1 − Bout2	0.21	(-0.70,1.13)	0.849
166 / 1004 Bouts with missing measurements.		Bout1 − Bout3	0.20	(-0.72,1.11)	0.870
		Bout2 − Bout3	−0.02	(-0.93,0.90)	0.999
	S : 5v5	Bout1 − Bout2	−0.11	(-0.72,0.51)	0.911
		Bout1 − Bout3	0.38	(-0.24,0.99)	0.318
		Bout2 − Bout3	0.49	(-0.09,1.07)	0.120
	S : 7v7	Bout1 − Bout2	0.03	(-0.55,0.61)	0.992
		Bout1 − Bout3	0.04	(-0.56,0.63)	0.989
		Bout2 − Bout3	0.01	(-0.59,0.60)	1.000
	M : 3v3	Bout1 − Bout2	0.40	(-0.66,1.46)	0.648
		Bout1 − Bout3	0.12	(-0.94,1.18)	0.960
		Bout2 − Bout3	−0.28	(-1.34,0.78)	0.811
	M : 5v5	Bout1 − Bout2	—		
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	M : 7v7	Bout1 − Bout2	−0.16	(-0.55,0.23)	0.593
		Bout1 − Bout3	0.20	(-0.19,0.60)	0.436
		Bout2 − Bout3	0.36	(-0.02,0.75)	0.069

U15	Pitch * No.	Comparison	Estimate	95% Adj. C.I.	Adj. *p*-value
	L : 3v3	Bout1 − Bout2	0.36	(-0.51,1.23)	0.595
		Bout1 − Bout3	−0.14	(-1.01,0.73)	0.924
		Bout2 − Bout3	−0.50	(-1.42,0.42)	0.406
	L : 5v5	Bout1 − Bout2	0.07	(-0.54,0.68)	0.962
		Bout1 − Bout3	−0.02	(-0.63,0.59)	0.997
		Bout2 − Bout3	−0.09	(-0.70,0.52)	0.940
	L : 7v7	Bout1 − Bout2	0.37	(-0.15,0.89)	0.215
		Bout1 − Bout3	0.15	(-0.37,0.67)	0.770
		Bout2 − Bout3	−0.22	(-0.73,0.29)	0.573
HRZ3 (min)	S : 3v3	Bout1 − Bout2	0.23	(-1.09,1.56)	0.910
166 / 1004 Bouts with missing measurements.		Bout1 − Bout3	−0.26	(-1.58,1.06)	0.887
		Bout2 − Bout3	−0.50	(-1.82,0.83)	0.652
	S : 5v5	Bout1 − Bout2	−0.26	(-1.15,0.63)	0.770
		Bout1 − Bout3	−0.03	(-0.92,0.85)	0.996
		Bout2 − Bout3	0.23	(-0.61,1.06)	0.800
	S : 7v7	Bout1 − Bout2	−0.54	(-1.37,0.30)	0.288
		Bout1 − Bout3	−0.85	(-1.71,0.01)	0.054
		Bout2 − Bout3	−0.31	(-1.17,0.55)	0.670
	M : 3v3	Bout1 − Bout2	0.90	(-0.63,2.43)	0.349
		Bout1 − Bout3	0.92	(-0.60,2.45)	0.332
		Bout2 − Bout3	0.02	(-1.50,1.55)	0.999
	M : 5v5	Bout1 − Bout2	—		
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	M : 7v7	Bout1 − Bout2	0.02	(-0.54,0.58)	0.996
		Bout1 − Bout3	0.09	(-0.47,0.66)	0.922
		Bout2 − Bout3	0.07	(-0.48,0.63)	0.949
	L : 3v3	Bout1 − Bout2	0.33	(-0.92,1.59)	0.807
		Bout1 − Bout3	−0.87	(-2.13,0.38)	0.230
		Bout2 − Bout3	−1.21	(-2.53,0.11)	0.081
	L : 5v5	Bout1 − Bout2	0.31	(-0.58,1.19)	0.694
		Bout1 − Bout3	−0.06	(-0.94,0.82)	0.985
		Bout2 − Bout3	−0.37	(-1.25,0.51)	0.592
	L : 7v7	Bout1 − Bout2	0.09	(-0.66,0.84)	0.958
		Bout1 − Bout3	0.03	(-0.72,0.78)	0.996
		Bout2 − Bout3	−0.06	(-0.79,0.67)	0.980
HRZ4 (min)	S : 3v3	Bout1 − Bout2	0.74	(-0.86,2.34)	0.525
166 / 1004 Bouts with missing measurements.		Bout1 − Bout3	0.82	(-0.77,2.42)	0.447
		Bout2 − Bout3	0.09	(-1.51,1.69)	0.991
	S : 5v5	Bout1 − Bout2	0.58	(-0.49,1.66)	0.406
		Bout1 − Bout3	0.37	(-0.70,1.45)	0.692
		Bout2 − Bout3	−0.21	(-1.22,0.80)	0.875
	S : 7v7	Bout1 − Bout2	0.32	(-0.69,1.33)	0.738
		Bout1 − Bout3	0.59	(-0.45,1.62)	0.383
		Bout2 − Bout3	0.27	(-0.77,1.30)	0.820

U15	Pitch * No.	Comparison	Estimate	95% Adj. C.I.	Adj. *p*-value
	M : 3v3	Bout1 − Bout2	−1.18	(-3.02,0.67)	0.292
		Bout1 − Bout3	−1.02	(-2.86,0.83)	0.399
		Bout2 − Bout3	0.16	(-1.69,2.01)	0.977
	M : 5v5	Bout1 − Bout2	—		
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	M : 7v7	Bout1 − Bout2	0.33	(-0.34,1.00)	0.484
		Bout1 − Bout3	0.07	(-0.61,0.75)	0.968
		Bout2 − Bout3	−0.26	(-0.93,0.41)	0.638
	L : 3v3	Bout1 − Bout2	−0.75	(-2.26,0.77)	0.479
		Bout1 − Bout3	−0.13	(-1.65,1.39)	0.978
		Bout2 − Bout3	0.62	(-0.98,2.22)	0.637
	L : 5v5	Bout1 − Bout2	−0.01	(-1.08,1.05)	1.000
		Bout1 − Bout3	0.04	(-1.03,1.11)	0.996
		Bout2 − Bout3	0.05	(-1.01,1.12)	0.992
	L : 7v7	Bout1 − Bout2	0.01	(-0.90,0.91)	1.000
		Bout1 − Bout3	0.22	(-0.69,1.12)	0.839
		Bout2 − Bout3	0.21	(-0.68,1.09)	0.847
HR_{Z5} (min)	S : 3v3	Bout1 − Bout2	−1.36	(-2.92,0.20)	0.102
166 / 1004 Bouts with missing measurements.		Bout1 − Bout3	−0.50	(-2.06,1.05)	0.728
		Bout2 − Bout3	0.85	(-0.70,2.41)	0.403
	S : 5v5	Bout1 − Bout2	−0.22	(-1.27,0.82)	0.870
		Bout1 − Bout3	−0.76	(-1.81,0.28)	0.199
		Bout2 − Bout3	−0.54	(-1.53,0.44)	0.401
	S : 7v7	Bout1 − Bout2	0.00	(-0.98,0.99)	1.000
		Bout1 − Bout3	0.07	(-0.94,1.09)	0.984
		Bout2 − Bout3	0.07	(-0.94,1.08)	0.985
	M : 3v3	Bout1 − Bout2	−0.53	(-2.33,1.27)	0.770
		Bout1 − Bout3	−0.20	(-2.00,1.60)	0.963
		Bout2 − Bout3	0.33	(-1.47,2.13)	0.904
	M : 5v5	Bout1 − Bout2	—		
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	M : 7v7	Bout1 − Bout2	−0.23	(-0.89,0.43)	0.685
		Bout1 − Bout3	−0.44	(-1.11,0.22)	0.260
		Bout2 − Bout3	−0.21	(-0.87,0.45)	0.729
	L : 3v3	Bout1 − Bout2	−0.43	(-1.91,1.04)	0.770
		Bout1 − Bout3	0.68	(-0.79,2.16)	0.523
		Bout2 − Bout3	1.12	(-0.44,2.67)	0.212
	L : 5v5	Bout1 − Bout2	−0.44	(-1.48,0.60)	0.579
		Bout1 − Bout3	−0.17	(-1.21,0.87)	0.920
		Bout2 − Bout3	0.27	(-0.77,1.31)	0.816
	L : 7v7	Bout1 − Bout2	−0.52	(-1.40,0.36)	0.347
		Bout1 − Bout3	−0.36	(-1.24,0.52)	0.602
		Bout2 − Bout3	0.16	(-0.70,1.03)	0.899

U16	Pitch * No.	Comparison	Estimate	95% Adj. C.I.	Adj. *p*-value
HR$_{Z1}$ (min)	S : 3v3	Bout1 − Bout2	−0.02	(-1.08,1.03)	0.998
166 / 1004 Bouts with missing measurements.		Bout1 − Bout3	0.00	(-1.05,1.05)	1.000
		Bout2 − Bout3	0.02	(-1.03,1.08)	0.998
	S : 5v5	Bout1 − Bout2	−0.00	(-1.49,1.49)	1.000
		Bout1 − Bout3	−0.00	(-1.49,1.49)	1.000
		Bout2 − Bout3	−0.00	(-1.49,1.49)	1.000
	S : 7v7	Bout1 − Bout2	0.09	(-0.76,0.95)	0.964
		Bout1 − Bout3	0.09	(-0.76,0.95)	0.964
		Bout2 − Bout3	0.00	(-0.86,0.86)	1.000
	M : 3v3	Bout1 − Bout2	0.05	(-0.46,0.56)	0.967
		Bout1 − Bout3	0.05	(-0.44,0.55)	0.965
		Bout2 − Bout3	−0.00	(-0.51,0.51)	1.000
	M : 5v5	Bout1 − Bout2	−0.00	(-1.49,1.49)	1.000
		Bout1 − Bout3	−0.00	(-1.49,1.49)	1.000
		Bout2 − Bout3	−0.00	(-1.49,1.49)	1.000
	M : 7v7	Bout1 − Bout2	−0.01	(-0.87,0.85)	0.999
		Bout1 − Bout3	0.00	(-0.86,0.86)	1.000
		Bout2 − Bout3	0.01	(-0.85,0.87)	0.999
	L : 3v3	Bout1 − Bout2	0.07	(-0.54,0.67)	0.964
		Bout1 − Bout3	0.07	(-0.54,0.67)	0.964
		Bout2 − Bout3	0.00	(-0.61,0.61)	1.000
	L : 5v5	Bout1 − Bout2	—		
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	L : 7v7	Bout1 − Bout2	0.03	(-0.71,0.77)	0.995
		Bout1 − Bout3	0.03	(-0.71,0.77)	0.995
		Bout2 − Bout3	0.00	(-0.74,0.74)	1.000
HR$_{Z2}$ (min)	S : 3v3	Bout1 − Bout2	−0.23	(-1.52,1.07)	0.912
166 / 1004 Bouts with missing measurements.		Bout1 − Bout3	−0.43	(-1.73,0.86)	0.712
		Bout2 − Bout3	−0.21	(-1.50,1.09)	0.924
	S : 5v5	Bout1 − Bout2	0.57	(-1.27,2.40)	0.748
		Bout1 − Bout3	0.38	(-1.45,2.22)	0.876
		Bout2 − Bout3	−0.18	(-2.02,1.65)	0.970
	S : 7v7	Bout1 − Bout2	0.16	(-0.90,1.22)	0.932
		Bout1 − Bout3	0.07	(-0.99,1.12)	0.988
		Bout2 − Bout3	−0.09	(-1.15,0.96)	0.976
	M : 3v3	Bout1 − Bout2	0.08	(-0.55,0.71)	0.952
		Bout1 − Bout3	−0.19	(-0.81,0.42)	0.735
		Bout2 − Bout3	−0.27	(-0.90,0.36)	0.562
	M : 5v5	Bout1 − Bout2	0.37	(-1.47,2.20)	0.886
		Bout1 − Bout3	0.10	(-1.73,1.93)	0.991
		Bout2 − Bout3	−0.27	(-2.10,1.57)	0.938
	M : 7v7	Bout1 − Bout2	0.54	(-0.52,1.60)	0.456
		Bout1 − Bout3	1.10	(0.04,2.16)	0.039
		Bout2 − Bout3	0.56	(-0.50,1.62)	0.427

U16	Pitch * No.	Comparison	Estimate	95% Adj. C.I.	Adj. *p*-value
	L : 3v3	Bout1 − Bout2	0.18	(-0.57,0.93)	0.842
		Bout1 − Bout3	0.20	(-0.55,0.95)	0.810
		Bout2 − Bout3	0.02	(-0.73,0.77)	0.998
	L : 5v5	Bout1 − Bout2	—		
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	L : 7v7	Bout1 − Bout2	0.32	(-0.60,1.23)	0.696
		Bout1 − Bout3	0.10	(-0.82,1.01)	0.967
		Bout2 − Bout3	−0.22	(-1.14,0.70)	0.838
HR_{Z3} (min)	S : 3v3	Bout1 − Bout2	−0.45	(-2.32,1.42)	0.839
166 / 1004 Bouts with missing measurements.		Bout1 − Bout3	−0.55	(-2.42,1.32)	0.769
		Bout2 − Bout3	−0.10	(-1.97,1.77)	0.991
	S : 5v5	Bout1 − Bout2	−0.17	(-2.81,2.48)	0.988
		Bout1 − Bout3	−0.43	(-3.08,2.21)	0.922
		Bout2 − Bout3	−0.27	(-2.91,2.38)	0.970
	S : 7v7	Bout1 − Bout2	0.23	(-1.30,1.75)	0.935
		Bout1 − Bout3	−0.41	(-1.93,1.12)	0.807
		Bout2 − Bout3	−0.63	(-2.16,0.89)	0.593
	M : 3v3	Bout1 − Bout2	0.05	(-0.86,0.96)	0.990
		Bout1 − Bout3	−0.40	(-1.28,0.48)	0.539
		Bout2 − Bout3	−0.45	(-1.36,0.46)	0.474
	M : 5v5	Bout1 − Bout2	−0.25	(-2.89,2.39)	0.973
		Bout1 − Bout3	0.02	(-2.63,2.66)	1.000
		Bout2 − Bout3	0.27	(-2.38,2.91)	0.970
	M : 7v7	Bout1 − Bout2	−0.24	(-1.77,1.28)	0.925
		Bout1 − Bout3	−0.67	(-2.19,0.86)	0.561
		Bout2 − Bout3	−0.42	(-1.95,1.10)	0.793
	L : 3v3	Bout1 − Bout2	−0.15	(-1.23,0.93)	0.945
		Bout1 − Bout3	−0.24	(-1.32,0.84)	0.862
		Bout2 − Bout3	−0.09	(-1.17,0.99)	0.978
	L : 5v5	Bout1 − Bout2	—		
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	L : 7v7	Bout1 − Bout2	0.83	(-0.49,2.16)	0.301
		Bout1 − Bout3	0.20	(-1.12,1.53)	0.930
		Bout2 − Bout3	−0.63	(-1.95,0.69)	0.503
HR_{Z4} (min)	S : 3v3	Bout1 − Bout2	1.19	(-1.07,3.45)	0.431
166 / 1004 Bouts with missing measurements.		Bout1 − Bout3	0.78	(-1.48,3.04)	0.695
		Bout2 − Bout3	−0.41	(-2.67,1.85)	0.906
	S : 5v5	Bout1 − Bout2	1.47	(-1.73,4.66)	0.529
		Bout1 − Bout3	0.35	(-2.85,3.55)	0.964
		Bout2 − Bout3	−1.12	(-4.31,2.08)	0.691
	S : 7v7	Bout1 − Bout2	0.12	(-1.73,1.96)	0.988
		Bout1 − Bout3	0.02	(-1.82,1.87)	1.000
		Bout2 − Bout3	−0.09	(-1.94,1.75)	0.992

U16	Pitch * No.	Comparison	Estimate	95% Adj. C.I.	Adj. *p*-value
	M : 3v3	Bout1 − Bout2	0.35	(-0.75,1.45)	0.733
		Bout1 − Bout3	0.68	(-0.39,1.74)	0.295
		Bout2 − Bout3	0.33	(-0.77,1.42)	0.766
	M : 5v5	Bout1 − Bout2	1.58	(-1.61,4.78)	0.476
		Bout1 − Bout3	0.97	(-2.23,4.16)	0.758
		Bout2 − Bout3	−0.62	(-3.81,2.58)	0.893
	M : 7v7	Bout1 − Bout2	−0.33	(-2.17,1.52)	0.909
		Bout1 − Bout3	−0.41	(-2.26,1.44)	0.860
		Bout2 − Bout3	−0.08	(-1.93,1.76)	0.994
	L : 3v3	Bout1 − Bout2	1.30	(-0.01,2.61)	0.051
		Bout1 − Bout3	1.20	(-0.11,2.50)	0.080
		Bout2 − Bout3	−0.10	(-1.41,1.20)	0.981
	L : 5v5	Bout1 − Bout2	—		
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	L : 7v7	Bout1 − Bout2	−0.31	(-1.91,1.29)	0.890
		Bout1 − Bout3	0.15	(-1.44,1.75)	0.972
		Bout2 − Bout3	0.47	(-1.13,2.07)	0.772
HR_{Z5} (min)	S : 3v3	Bout1 − Bout2	−0.48	(-2.69,1.72)	0.864
166 / 1004 Bouts with missing measurements.		Bout1 − Bout3	0.20	(-2.00,2.40)	0.975
		Bout2 − Bout3	0.68	(-1.52,2.89)	0.747
	S : 5v5	Bout1 − Bout2	−2.03	(-5.15,1.08)	0.276
		Bout1 − Bout3	−0.30	(-3.42,2.82)	0.972
		Bout2 − Bout3	1.73	(-1.38,4.85)	0.392
	S : 7v7	Bout1 − Bout2	−0.61	(-2.41,1.19)	0.705
		Bout1 − Bout3	0.22	(-1.58,2.02)	0.957
		Bout2 − Bout3	0.83	(-0.97,2.63)	0.526
	M : 3v3	Bout1 − Bout2	−0.53	(-1.61,0.54)	0.470
		Bout1 − Bout3	−0.14	(-1.18,0.90)	0.947
		Bout2 − Bout3	0.40	(-0.68,1.47)	0.661
	M : 5v5	Bout1 − Bout2	−1.82	(-4.93,1.30)	0.358
		Bout1 − Bout3	−1.10	(-4.22,2.02)	0.685
		Bout2 − Bout3	0.72	(-2.40,3.83)	0.852
	M : 7v7	Bout1 − Bout2	0.12	(-1.68,1.92)	0.987
		Bout1 − Bout3	0.04	(-1.75,1.84)	0.998
		Bout2 − Bout3	−0.07	(-1.87,1.73)	0.995
	L : 3v3	Bout1 − Bout2	−1.35	(-2.62,-0.08)	0.035
		Bout1 − Bout3	−1.17	(-2.44,0.10)	0.078
		Bout2 − Bout3	0.18	(-1.10,1.45)	0.944
	L : 5v5	Bout1 − Bout2	—		
		Bout1 − Bout3	—		
		Bout2 − Bout3	—		
	L : 7v7	Bout1 − Bout2	−0.87	(-2.42,0.69)	0.392
		Bout1 − Bout3	−0.55	(-2.11,1.01)	0.685
		Bout2 − Bout3	0.32	(-1.24,1.87)	0.882

U18	Pitch * No.	Comparison	Estimate	95% Adj. C.I.	Adj. *p*-value
HR$_{Z1}$ (min)	S : 3v3	Bout1 − Bout2	0.19	(-0.13,0.50)	0.337
166 / 1004 Bouts with missing measurements.		Bout1 − Bout3	0.15	(-0.16,0.47)	0.478
		Bout2 − Bout3	−0.03	(-0.34,0.28)	0.965
	S : 5v5	Bout1 − Bout2	0.18	(-0.38,0.74)	0.736
		Bout1 − Bout3	0.23	(-0.34,0.79)	0.611
		Bout2 − Bout3	0.05	(-0.51,0.61)	0.978
	S : 7v7	Bout1 − Bout2	0.02	(-0.44,0.49)	0.991
		Bout1 − Bout3	0.02	(-0.44,0.49)	0.991
		Bout2 − Bout3	−0.00	(-0.47,0.47)	1.000
	M : 3v3	Bout1 − Bout2	0.03	(-0.35,0.40)	0.986
		Bout1 − Bout3	0.02	(-0.36,0.41)	0.989
		Bout2 − Bout3	−0.00	(-0.38,0.38)	1.000
	M : 5v5	Bout1 − Bout2	0.00	(-0.66,0.66)	1.000
		Bout1 − Bout3	−0.08	(-0.71,0.56)	0.956
		Bout2 − Bout3	−0.08	(-0.71,0.56)	0.956
	M : 7v7	Bout1 − Bout2	0.03	(-0.44,0.50)	0.988
		Bout1 − Bout3	0.03	(-0.44,0.50)	0.985
		Bout2 − Bout3	0.00	(-0.47,0.47)	1.000
	L : 3v3	Bout1 − Bout2	0.08	(-0.30,0.46)	0.869
		Bout1 − Bout3	0.13	(-0.25,0.51)	0.697
		Bout2 − Bout3	0.05	(-0.33,0.43)	0.952
	L : 5v5	Bout1 − Bout2	0.34	(-0.03,0.71)	0.079
		Bout1 − Bout3	0.35	(-0.02,0.71)	0.069
		Bout2 − Bout3	0.01	(-0.34,0.36)	0.998
	L : 7v7	Bout1 − Bout2	0.40	(0.06,0.74)	0.016
		Bout1 − Bout3	0.36	(0.02,0.71)	0.038
		Bout2 − Bout3	−0.04	(-0.39,0.31)	0.959
HR$_{Z2}$ (min)	S : 3v3	Bout1 − Bout2	0.23	(-0.16,0.62)	0.339
166 / 1004 Bouts with missing measurements.		Bout1 − Bout3	0.15	(-0.24,0.54)	0.636
		Bout2 − Bout3	−0.08	(-0.46,0.30)	0.870
	S : 5v5	Bout1 − Bout2	0.10	(-0.59,0.80)	0.936
		Bout1 − Bout3	−0.10	(-0.79,0.60)	0.941
		Bout2 − Bout3	−0.20	(-0.89,0.49)	0.776
	S : 7v7	Bout1 − Bout2	0.16	(-0.42,0.74)	0.790
		Bout1 − Bout3	0.22	(-0.36,0.80)	0.650
		Bout2 − Bout3	0.06	(-0.52,0.64)	0.971
	M : 3v3	Bout1 − Bout2	0.20	(-0.27,0.66)	0.577
		Bout1 − Bout3	0.03	(-0.44,0.51)	0.984
		Bout2 − Bout3	−0.16	(-0.63,0.30)	0.686
	M : 5v5	Bout1 − Bout2	0.09	(-0.73,0.91)	0.967
		Bout1 − Bout3	0.18	(-0.60,0.97)	0.850
		Bout2 − Bout3	0.09	(-0.69,0.88)	0.956
	M : 7v7	Bout1 − Bout2	0.33	(-0.25,0.91)	0.379
		Bout1 − Bout3	0.44	(-0.14,1.02)	0.172

U18	Pitch * No.	Comparison	Estimate	95% Adj. C.I.	Adj. *p*-value
		Bout2 − Bout3	0.11	(-0.46,0.69)	0.887
	L : 3v3	Bout1 − Bout2	0.12	(-0.35,0.58)	0.828
		Bout1 − Bout3	0.22	(-0.25,0.69)	0.507
		Bout2 − Bout3	0.10	(-0.37,0.58)	0.862
	L : 5v5	Bout1 − Bout2	0.08	(-0.38,0.53)	0.914
		Bout1 − Bout3	0.13	(-0.32,0.58)	0.774
		Bout2 − Bout3	0.05	(-0.38,0.49)	0.954
	L : 7v7	Bout1 − Bout2	0.21	(-0.21,0.63)	0.456
		Bout1 − Bout3	0.30	(-0.12,0.73)	0.218
		Bout2 − Bout3	0.09	(-0.34,0.52)	0.876
HR$_{Z3}$ (min)	S : 3v3	Bout1 − Bout2	−0.05	(-0.60,0.51)	0.980
166 / 1004 Bouts with missing measurements.		Bout1 − Bout3	−0.05	(-0.61,0.51)	0.974
		Bout2 − Bout3	−0.01	(-0.56,0.54)	0.999
	S : 5v5	Bout1 − Bout2	−0.05	(-1.05,0.95)	0.993
		Bout1 − Bout3	−0.43	(-1.43,0.57)	0.572
		Bout2 − Bout3	−0.38	(-1.38,0.62)	0.643
	S : 7v7	Bout1 − Bout2	0.44	(-0.39,1.28)	0.430
		Bout1 − Bout3	0.87	(0.04,1.71)	0.039
		Bout2 − Bout3	0.43	(-0.41,1.27)	0.449
	M : 3v3	Bout1 − Bout2	−0.01	(-0.68,0.66)	0.999
		Bout1 − Bout3	−0.42	(-1.10,0.26)	0.315
		Bout2 − Bout3	−0.41	(-1.08,0.26)	0.324
	M : 5v5	Bout1 − Bout2	−0.55	(-1.73,0.64)	0.523
		Bout1 − Bout3	−0.53	(-1.66,0.60)	0.517
		Bout2 − Bout3	0.02	(-1.11,1.15)	0.999
	M : 7v7	Bout1 − Bout2	0.00	(-0.83,0.84)	1.000
		Bout1 − Bout3	−0.27	(-1.10,0.57)	0.737
		Bout2 − Bout3	−0.27	(-1.10,0.57)	0.734
	L : 3v3	Bout1 − Bout2	0.04	(-0.63,0.71)	0.989
		Bout1 − Bout3	0.08	(-0.59,0.75)	0.960
		Bout2 − Bout3	0.04	(-0.65,0.72)	0.991
	L : 5v5	Bout1 − Bout2	0.14	(-0.51,0.79)	0.869
		Bout1 − Bout3	0.18	(-0.48,0.83)	0.801
		Bout2 − Bout3	0.04	(-0.59,0.66)	0.990
	L : 7v7	Bout1 − Bout2	−0.12	(-0.72,0.49)	0.894
		Bout1 − Bout3	−0.21	(-0.83,0.40)	0.692
		Bout2 − Bout3	−0.10	(-0.71,0.52)	0.927
HR$_{Z4}$ (min)	S : 3v3	Bout1 − Bout2	0.36	(-0.32,1.03)	0.431
166 / 1004 Bouts with missing measurements.		Bout1 − Bout3	0.28	(-0.39,0.96)	0.584
		Bout2 − Bout3	−0.07	(-0.74,0.60)	0.965
	S : 5v5	Bout1 − Bout2	−0.08	(-1.29,1.13)	0.986
		Bout1 − Bout3	0.31	(-0.90,1.52)	0.822
		Bout2 − Bout3	0.39	(-0.82,1.60)	0.728
	S : 7v7	Bout1 − Bout2	0.20	(-0.81,1.21)	0.888
		Bout1 − Bout3	0.01	(-1.00,1.02)	1.000

U18	Pitch * No.	Comparison	Estimate	95% Adj. C.I.	Adj. *p*-value
		Bout2 − Bout3	−0.19	(-1.20,0.82)	0.895
	M : 3v3	Bout1 − Bout2	0.20	(-0.61,1.01)	0.831
		Bout1 − Bout3	0.30	(-0.53,1.12)	0.678
		Bout2 − Bout3	0.09	(-0.72,0.91)	0.959
	M : 5v5	Bout1 − Bout2	0.18	(-1.25,1.61)	0.955
		Bout1 − Bout3	−0.20	(-1.57,1.17)	0.940
		Bout2 − Bout3	−0.37	(-1.74,1.00)	0.798
	M : 7v7	Bout1 − Bout2	−0.09	(-1.10,0.93)	0.979
		Bout1 − Bout3	0.19	(-0.83,1.20)	0.903
		Bout2 − Bout3	0.27	(-0.74,1.28)	0.805
	L : 3v3	Bout1 − Bout2	0.06	(-0.75,0.87)	0.984
		Bout1 − Bout3	0.18	(-0.63,1.00)	0.856
		Bout2 − Bout3	0.12	(-0.70,0.95)	0.933
	L : 5v5	Bout1 − Bout2	−0.04	(-0.83,0.75)	0.992
		Bout1 − Bout3	0.10	(-0.69,0.89)	0.956
		Bout2 − Bout3	0.14	(-0.62,0.89)	0.906
	L : 7v7	Bout1 − Bout2	−0.38	(-1.12,0.35)	0.439
		Bout1 − Bout3	−0.28	(-1.02,0.46)	0.651
		Bout2 − Bout3	0.10	(-0.64,0.85)	0.944
HR_{Z5} (min)	S : 3v3	Bout1 − Bout2	−0.72	(-1.38,-0.06)	0.027
166 / 1004 Bouts with missing measurements.		Bout1 − Bout3	−0.49	(-1.14,0.17)	0.193
		Bout2 − Bout3	0.24	(-0.41,0.89)	0.671
	S : 5v5	Bout1 − Bout2	−0.30	(-1.48,0.88)	0.821
		Bout1 − Bout3	−0.01	(-1.19,1.17)	1.000
		Bout2 − Bout3	0.29	(-0.89,1.47)	0.834
	S : 7v7	Bout1 − Bout2	−0.82	(-1.81,0.16)	0.121
		Bout1 − Bout3	−1.11	(-2.10,-0.13)	0.022
		Bout2 − Bout3	−0.29	(-1.28,0.70)	0.769
	M : 3v3	Bout1 − Bout2	−0.41	(-1.20,0.38)	0.448
		Bout1 − Bout3	0.07	(-0.73,0.88)	0.974
		Bout2 − Bout3	0.48	(-0.31,1.27)	0.326
	M : 5v5	Bout1 − Bout2	0.17	(-1.22,1.56)	0.956
		Bout1 − Bout3	0.62	(-0.72,1.95)	0.522
		Bout2 − Bout3	0.45	(-0.89,1.78)	0.710
	M : 7v7	Bout1 − Bout2	−0.21	(-1.20,0.78)	0.871
		Bout1 − Bout3	−0.32	(-1.31,0.66)	0.721
		Bout2 − Bout3	−0.11	(-1.10,0.87)	0.961
	L : 3v3	Bout1 − Bout2	−0.24	(-1.04,0.55)	0.749
		Bout1 − Bout3	−0.55	(-1.35,0.24)	0.228
		Bout2 − Bout3	−0.31	(-1.11,0.49)	0.637
	L : 5v5	Bout1 − Bout2	−0.54	(-1.31,0.23)	0.222
		Bout1 − Bout3	−0.74	(-1.51,0.03)	0.065
		Bout2 − Bout3	−0.19	(-0.93,0.54)	0.813
	L : 7v7	Bout1 − Bout2	−0.19	(-0.91,0.52)	0.805
		Bout1 − Bout3	−0.25	(-0.97,0.48)	0.700
		Bout2 − Bout3	−0.06	(-0.78,0.67)	0.981

Appendix 17: Youth SSG core performance measures (complete cases - SPSS)

MEAN ± SD per core performance outcome measure for SSG formats

			SSG (Bout avg.)	
			YOUTH	
		Small	Medium	Large
V_{AVG} (m.min^{-1})	3v3	79.8 ± 13.5	82.9 ± 10.0	89.9 ± 9.5
		(87.9 ± 12.6)	(97.4 ± 15.7)	(105.0 ± 19.3)
	5v5	70.0 ± 7.6	70.3 ± 7.4	81.6 ± 12.2
		(78.7 ± 14.3)	(86.5 ± 10.8)	(101.0 ± 17.9)
	7v7	71.4 ± 6.3	77.8 ± 8.5	90.2 ± 11.6
		(79.4 ± 9.0)	(92.0 ± 15.6)	(96.2 ± 15.2)
HIR (m)	3v3	43.7 ± 29.8	111.0 ± 62.6	150 ± 72.4
		(13.0 ± 13.0)	(33.4 ± 25.5)	(45.8 ± 34.3)
	5v5	21.9 ± 12.9	58.1 ± 39.3	85.9 ± 54.9
		(9.3 ± 11.4)	(17.5 ± 16.3)	(29.7 ± 23.8)
	7v7	20.8 ± 20.8	73.6 ± 56.9	44.8 ± 29.5
		(5.6 ± 8.5)	(21.4 ± 20.7)	(13.9 ± 13.5)
Sprint rate (min^{-1})	3v3	2.0 ± 0.6	2.1 ± 0.4	2.1 ± 0.6
		(2.7 ± 0.9)	(2.9 ± 0.8)	(2.9 ± 1.1)
	5v5	2.0 ± 0.7	1.9 ± 0.4	2.1 ± 0.7
		(2.4 ± 1.2)	(2.7 ± 0.7)	(3.0 ± 1.2)
	7v7	1.9 ± 0.6	2.1 ± 0.5	2.3 ± 0.6
		(2.4 ± 0.9)	(2.8 ± 1.0)	(2.9 ± 1.1)
V_{MAX} (Km.h^{-1})	3v3	23.7 ± 2.6	25.9 ± 2.7	27.3 ± 3.3
		(20.9 ± 3.0)	(23.6 ± 3.3)	(24.3 ± 3.7)
	5v5	22.8 ± 2.3	26.1 ± 3.3	24.5 ± 3.6
		(20.3 ± 4.0)	(22.4 ± 3.7)	(22.5 ± 4.3)
	7v7	21.7 ± 2.6	25.1 ± 3.2	24.3 ± 2.9
		(19.5 ± 2.6)	(22.5 ± 3.7)	(21.6 ± 3.3)
HR_{AVG} (% HR_{MAX})	3v3	80.6 ± 6.5	81.9 ± 4.2	82.1 ± 3.6
		(82.5 ± 7.3)	(83.6 ± 6.1)	(84.3 ± 5.5)
	5v5	79.0 ± 5.3	77.8 ± 4.2	76.4 ± 8.8
		(81.2 ± 6.5)	(81.3 ± 4.7)	(80.2 ± 9.6)
	7v7	76.8 ± 6.3	76.6 ± 6.6	81.1 ± 6.8
		(79.0 ± 8.0)	(79.1 ± 8.3)	(82.8 ± 7.7)

Time >90% HR$_{MAX}$ (min)	3v3	±	±	±
		(±)	(±)	(±)
	5v5	±	±	±
		(±)	(±)	(±)
	7v7	±	±	±
		(±)	(±)	(±)
RPE (6-20)	3v3	12.0 ± 1.9	13.6 ± 2.3	14.5 ± 2.4
		(11.6 ± 2.5)	(12.5 ± 2.5)	(13.3 ± 2.3)
	5v5	12.6 ± 2.1	15.1 ± 1.5	12.6 ± 2.4
		(11.2 ± 1.8)	(12.8 ± 2.3)	(11.5 ± 2.5)
	7v7	10.5 ± 1.4	12.3 ± 2.4	12.1 ± 1.2
		(9.6 ± 1.8)	(11.1 ± 2.4)	(11.6 ± 1.5)
			U14	
		Small	Medium	Large
V$_{AVG}$ (m.min^{-1})	3v3	79.8 ± 6.5	79.9 ± 10.9	83.3 ± 11.1
		(87.6 ± 13.7)	(91.2 ± 16.3)	(103.1 ± 28.5)
	5v5	-	70.3 ± 7.4	-
		(70.6 ± 10.9)	(86.5 ± 10.8)	(-)
	7v7	-	69.8 ± 12.9	-
		(-)	(74.9 ± 15.6)	(79.0 ± 10.6)
HIR (m)	3v3	27.8 ± 25.3	83.0 ± 47.2	169.8 ± 135.5
		(8.3 ± 10.5)	(24.3 ± 18.7)	(46.1 ± 50.2)
	5v5	-	58.1 ± 39.3	-
		(14.1 ± 13.6)	(17.5 ± 16.3)	(-)
	7v7	-	28.2 ± 37.6	-
		(-)	(5.9 ± 10.1)	(12.0 ± 11.5)
Sprint rate (min^{-1})	3v3	2.1 ± 0.3	2.1 ± 0.3	1.9 ± 0.9
		(2.7 ± 0.7)	(2.6 ± 0.7)	(2.5 ± 1.3)
	5v5	-	1.9 ± 0.4	-
		(1.7 ± 0.9)	(2.7 ± 0.7)	(-)
	7v7	-	1.5 ± 0.6	-
		(-)	(1.8 ± 0.8)	(1.8 ± 0.8)
V$_{MAX}$ (Km.h^{-1})	3v3	23.0 ± 3.4	26.1 ± 2.8	30.1 ± 5.5
		(20.2 ± 2.8)	(23.3 ± 3.4)	(24.3 ± 5.4)
	5v5	-	26.1 ± 3.3	-
		(20.9 ± 5.4)	(22.4 ± 3.7)	(-)
	7v7	-	21.4 ± 1.0	-
		(-)	(18.8 ± 2.3)	(21.5 ± 4.1)

HR_{AVG} (% HR_{MAX})	3v3	81.5 ± 2.5	82.9 ± 6.2	81.8 ± 3.4
		(82.2 ± 8.2)	(82.9 ± 8.3)	(83.0 ± 4.7)
	5v5	-	77.8 ± 4.2	(-)
		(79.7 ± 5.8)	(81.3 ± 4.7)	(-)
	7v7	-	68.4 ± 7.5	-
		(-)	(70.0 ± 9.0)	(77.0 ± 6.3)
Time >90% HR_{MAX} (min)	3v3	±	±	±
		(±)	(±)	(±)
	5v5	±	±	±
		(±)	(±)	(±)
	7v7	±	±	±
		(±)	(±)	(±)
RPE (6-20)	3v3	10.0 ± 0.0	12.3 ± 3.1	12.3 ± 2.2
		(9.7 ± 2.5)	(10.9 ± 2.7)	(11.4 ± 2.0)
	5v5	-	15.1 ± 1.5	-
		(11.4 ± 1.6)	(12.8 ± 2.3)	(-)
	7v7	-	9.0 ± 1.2	-
		(-)	(8.8 ± 2.0)	(11.5 ± 1.8)

			U15	
		Small	Medium	Large
V_{AVG} (m.min^{-1})	3v3	99.0 ± 12.9	92.3 ± 11.9	94.5 ± 4.0
		(96.1 ± 12.0)	(95.3 ± 14.3)	(93.8 ± 12.9)
	5v5	70.0 ± 7.6	-	83.4 ± 11.9
		(84.0 ± 13.9)	(-)	(103.1 ± 16.9)
	7v7	67.2 ± 6.4	77.4 ± 7.1	81.8 ± 7.0
		(74.6 ± 8.8)	(97.4 ± 14.2)	(97.0 ± 11.1)
HIR (m)	3v3	44.3 ± 34.0	118.7 ± 103.2	105.0 ± 45.0
		(14.8 ± 14.9)	(39.0 ± 32.9)	(30.6 ± 26.7)
	5v5	21.9 ± 12.9	-	109.8 ± 61.7
		(6.3 ± 8.6)	(-)	(36.0 ± 25.0)
	7v7	35.0 ± 23.7	82.8 ± 62.0	46.8 ± 29.9
		(9.0 ± 11.6)	(24.4 ± 21.1)	(15.1 ± 14.4)
Sprint rate (min^{-1})	3v3	2.1 ± 0.4	1.9 ± 0.3	1.8 ± 0.2
		(2.9 ± 0.8)	(2.4 ± 0.6)	(2.2 ± 0.6)
	5v5	2.0 ± 0.7	-	2.3 ± 0.6
		(2.8 ± 1.2)	(-)	(3.3 ± 1.0)
	7v7	1.6 ± 0.5	2.1 ± 0.5	2.0 ± 0.5
		(1.9 ± 0.7)	(3.1 ± 1.0)	(2.8 ± 1.0)
V_{MAX} (Km.h^{-1})	3v3	23.9 ± 3.0	24.7 ± 4.8	27.3 ± 3.6

		(21.3 ± 3.1)	(23.1 ± 4.0)	(23.7 ± 4.3)
	5v5	22.8 ± 2.3	-	25.5 ± 3.5
		(20 ± 2.8)	(-)	(23.7 ± 3.7)
	7v7	23.7 ± 2.5	25.3 ± 3.0	24.5 ± 2.4
		(20.4 ± 3.4)	(23.1 ± 3.2)	(21.9 ± 2.7)
HR_{AVG} (% HR_{MAX})	3v3	87.9 ± 4.0	81.9 ± 4.0	83.2 ± 5.0
		(89.0 ± 5.5)	(83.7 ± 5.3)	(83.9 ± 8.4)
	5v5	79.0 ± 5.3	-	78.7 ± 5.6
		(82.1 ± 6.9)	(-)	(82.2 ± 5.6)
	7v7	71.4 ± 5.0	76.4 ± 6.2	78.7 ± 7.8
		(72.2 ± 6.3)	(79.5 ± 7.4)	(83.0 ± 6.7)
Time >90% HR_{MAX} (min)	3v3	±	±	±
		(±)	(±)	(±)
	5v5	±	±	±
		(±)	(±)	(±)
	7v7	±	±	±
		(±)	(±)	(±)
RPE (6-20)	3v3	13.0 ± 0.8	13.0 ± 1.7	13.3 ± 2.9
		(12.7 ± 1.1)	(12.3 ± 1.6)	(12.7 ± 1.9)
	5v5	12.6 ± 2.1	-	14.1 ± 1.1
		(11.0 ± 2.0)	(-)	(13.3 ± 1.2)
	7v7	9.6 ± 1.4	12.3 ± 2.5	12.4 ± 1.0
		(9.0 ± 2.0)	(11.2 ± 2.3)	(12.0 ± 1.2)

			U16	
		Small	Medium	Large
V_{AVG} (m.min^{-1})	3v3	81.5 ± 6.4	90.8 ± 4.1	98.0 ± 4.6
		(96.8 ± 9.3)	(111.8 ± 12.2)	(118.4 ± 11.0)
	5v5	-	-	-
		(-)	(-)	(-)
	7v7	75.7 ± 4.9	85.3 ± 4.6	100.0 ± 11.4
		(84.7 ± 7.6)	(91.3 ± 14.1)	(107.2 ± 16.6)
HIR (m)	3v3	68.0 ± 33.9	158.8 ± 43.3	167.3 ± 8.0
		(22.0 ± 18.3)	(47.9 ± 31.3)	(50.8 ± 29.5)
	5v5	-	-	-
		(-)	(-)	(-)
	7v7	9.0 ± 7.8	52.0 ± 34.6	49.3 ± 23.1
		(2.9 ± 3.2)	(17.1 ± 13.2)	(16.2 ± 14.8)
Sprint rate (min^{-1})	3v3	2.3 ± 0.2	2.6 ± 0.4	2.7 ± 0.6
		(3.3 ± 0.4)	(3.8 ± 0.8)	(3.9 ± 0.9)

	5v5	- (-)	- (-)	- (-)
	7v7	2.5 ± 0.8 (3.3 ± 0.9)	2.1 ± 0.6 (2.6 ± 0.9)	2.8 ± 0.9 (3.7 ± 1.3)
V_{MAX} (Km.h^{-1})	3v3	24.3 ± 1.9 (21.9 ± 2.6)	25.9 ± 2.5 (23.7 ± 2.6)	25.2 ± 0.4 (23.7 ± 1.7)
	5v5	- (-)	- (-)	- (-)
	7v7	20.0 ± 0.4 (18.8 ± 1.3)	24.0 ± 3.9 (22.1 ± 3.7)	25.7 ± 4.5 (21.8 ± 4.3)
HR_{AVG} (% HR_{MAX})	3v3	77.7 ± 4.7 (81.4 ± 4.7)	81.0 ± 2.5 (84.2 ± 3.6)	83.4 ± 2.4 (86.7 ± 3.3)
	5v5	- (-)	- (-)	- (-)
	7v7	77.6 ± 2.7 (80.1 ± 3.6)	75.5 ± 2.5 (78.3 ± 5.4)	82.0 ± 5.2 (83.7 ± 6.1)
Time >90% HR_{MAX} (min)	3v3	± (±)	± (±)	± (±)
	5v5	± (±)	± (±)	± (±)
	7v7	± (±)	± (±)	± (±)
RPE (6-20)	3v3	14.0 ± 1.4 (13.2 ± 1.2)	14.3 ± 1.0 (13.9 ± 1.0)	16.3 ± 1.2 (15.1 ± 1.8)
	5v5	- (-)	- (-)	- (-)
	7v7	10.3 ± 0.6 (10.0 ± 1.0)	13.3 ± 1.2 (11.3 ± 1.9)	11.7 ± 1.5 (10.8 ± 1.6)
			U18	
		Small	Medium	Large
V_{AVG} (m.min^{-1})	3v3	73.2 ± 10.4 (84.0 ± 10.9)	78.4 ± 6.1 (100.2 ± 12.0)	87.6 ± 9.8 (107.4 ± 12.7)
	5v5	- (-)	- (-)	79.8 ± 12.8 (99.2 ± 18.8)
	7v7	74.4 ± 3.7 (82.5 ± 7.3)	80.3 ± 7.2 (92.5 ± 9.7)	98.3 ± 8.3 (105.1 ± 10.7)
HIR (m)	3v3	44.8 ± 30.0 (14.1 ± 12.2)	112.3 ± 63.4 (36.9 ± 24.9)	156.1 ± 56.2 (51.9 ± 23.8)
	5v5	-	-	62.0 ± 36.1

		(-)	(-)	(24.5 ± 21.8)
	7v7	10.2 ± 9.5	83.5 ± 51.2	40.8 ± 32.7
		(3.1 ± 3.8)	(27.2 ± 22.4)	(13.3 ± 13.7)
Sprint rate (min^{-1})	3v3	1.9 ± 0.8	2.0 ± 0.3	2.2 ± 0.5
		(2.6 ± 1.0)	(3.1 ± 0.7)	(3.2 ± 0.8)
	5v5	-	-	2.0 ± 0.8
		(-)	(-)	(2.8 ± 1.3)
	7v7	2.0 ± 0.4	2.2 ± 0.4	2.7 ± 0.4
		(2.7 ± 0.7)	(3.0 ± 0.9)	(3.7 ± 0.8)
V_{MAX} ($Km.h^{-1}$)	3v3	23.7 ± 2.6	26.2 ± 2.4	26.6 ± 1.9
		(21.2 ± 3.2)	(24.2 ± 3.4)	(24.7 ± 2.5)
	5v5	-	-	23.5 ± 3.7
		(-)	(-)	(21.5 ± 4.6)
	7v7	20.2 ± 1.4	27.0 ± 2.7	23.6 ± 3.3
		(18.8 ± 1.6)	(23.8 ± 4.1)	(21.2 ± 3.1)
HR_{AVG} (% HR_{MAX})	3v3	78.3 ± 6.7	81.2 ± 2.8	81.3 ± 3.9
		(80.9 ± 6.7)	(84.4 ± 3.7)	(84.7 ± 4.8)
	5v5	-	-	74.2 ± 11.1
		(-)	(-)	(78.6 ± 11.8)
	7v7	81.9 ± 3.0	81.6 ± 2.4	84.0 ± 4.8
		(85.1 ± 4.4)	(84.7 ± 4.2)	(86.6 ± 8.0)
Time >90% HR_{MAX} (min)	3v3	±	±	±
		(±)	(±)	(±)
	5v5	±	±	±
		(±)	(±)	(±)
	7v7	±	±	±
		(±)	(±)	(±)
RPE (6-20)	3v3	12.0 ± 2.0	14.9 ± 1.2	15.6 ± 1.3
		(12.3 ± 2.3)	(14.2 ± 1.5)	(14.4 ± 1.6)
	5v5	-	-	11.1 ± 2.4
		(-)	(-)	(10.0 ± 2.2)
	7v7	11.5 ± 0.8	13.7 ± 1.2	11.9 ± 1.4
		(10.0 ± 1.7)	(12.6 ± 1.6)	(11.5 ± 1.4)

Appendix 18: Thesis co-authorship forms

THE UNIVERSITY OF WAIKATO
Te Whare Wānanga o Waikato

Co-Authorship Form

Postgraduate Studies Office
Student and Academic Services Division
Wahanga Ratonga Matauranga Akonga
The University of Waikato
Private Bag 3105
Hamilton 3240, New Zealand
Phone +64 7 838 4439
Website:
http://www.waikato.ac.nz/sasd/postgraduate/

This form is to accompany the submission of any PhD that contains research reported in published or unpublished co-authored work. **Please include one copy of this form for each co-authored work**. Completed forms should be included in your appendices for all the copies of your thesis submitted for examination and library deposit (including digital deposit).

Please indicate the chapter/section/pages of this thesis that are extracted from a co-authored work and give the title and publication details or details of submission of the co-authored work.

Chapter 2: Large and small-sided game-play in rugby: a scoping narrative review

Nature of contribution by PhD candidate	Development of the research question, literature search, study selection, data extraction and interpretation, summarising and synthesising, manuscript preparation, revision.
Extent of contribution by PhD candidate (%)	95%

CO-AUTHORS

Name	Nature of Contribution
Beaven M.C.	Supervision, revision, and final manuscript revision
Gill N.D.	Supervision, final manuscript revision
McMaster T.D.	Supervision, revision, and final manuscript revision

Certification by Co-Authors

The undersigned hereby certify that:

- the above statement correctly reflects the nature and extent of the PhD candidate's contribution to this work, and the nature of the contribution of each of the co-authors; and

Name	Signature	Date
Beaven M.C.		21/11/2023
Gill N.D.		21/11/2023
McMaster T.D.		21/11/2023

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[redacted]

Please indicate the chapter/section/pages of this thesis that are extracted from a co-authored work and give the title and publication details or details of submission of the co-authored work.

Chapter 4: A systematic literature review of small-sided games in rugby union.

Nature of contribution by PhD candidate	Development of the research question, literature search, study selection, data extraction and interpretation, quality assessment, risk of bias assessment, summarising and synthesising, manuscript preparation, revision, journal submission.
Extent of contribution by PhD candidate (%)	85%

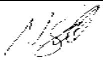
CO-AUTHORS

Name	Nature of Contribution
Beaven M.C.	Supervision, data extraction and interpretation, revision, final manuscript revision.
Gill N.D.	Supervision, revision, and final manuscript revision.
McMaster T.D.	Supervision, data interpretation, quality assessment, risk of bias assessment, revision, final manuscript revision.

Certification by Co-Authors

The undersigned hereby certify that:

❖ the above statement correctly reflects the nature and extent of the PhD candidate’s contribution to this work, and the nature of the contribution of each of the co-authors; and

Name	Signature	Date
Beaven M.C.		21/11/2023
Gill N.D.		21/11/2023
McMaster T.D.		21/11/2023

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Please indicate the chapter/section/pages of this thesis that are extracted from a co-authored work and give the title and publication details or details of submission of the co-authored work.

Chapter 5: Prevalence and implementation of small-sided games in rugby union practice
Wintershoven K., Beaven M.C., Gill N.D., & McMaster T.D. Prevalence and implementation of small-sided games in rugby union: a preliminary survey study. *The Journal of Sport and Exercise Science* 2023; 7: 1-11. DOI: 10.36905/jses.2023.01.01.

Nature of contribution by PhD candidate	Development of the research question, literature review, development of survey instrument, survey dispersion, data extraction and interpretation, statistical analysis, summarising and synthesising, manuscript preparation, revision, submission to journal.
Extent of contribution by PhD candidate (%)	95%

CO-AUTHORS

Name	Nature of Contribution
Beaven M.C.	Supervision, development of survey, revision, final manuscript revision
Gill N.D.	Supervision, development of survey, survey dispersion, revision, final manuscript revision
McMaster T.D.	Supervision, revision, final manuscript revision

Certification by Co-Authors

The undersigned hereby certify that:

❖ the above statement correctly reflects the nature and extent of the PhD candidate's contribution to this work, and the nature of the contribution of each of the co-authors; and

Name	Signature	Date
Beaven M.C		21/11/2023
Gill N.D.		21/11/2023
McMaster T.D.		21/11/2023

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[redacted]

Please indicate the chapter/section/pages of this thesis that are extracted from a co-authored work and give the title and publication details or details of submission of the co-authored work.

Chapter 6: Design of small-sided games in rugby union: a practice-informed perspective
Wintershoven K., Beaven M.C., Gill N.D., & McMaster T.D. How coaches design small-sided games in rugby union: a practice-based review. *Movement & Sport Sciences - Science & Motricité* 2023. (Accepted)

Nature of contribution by PhD candidate	Development of the research question, literature review, development of survey instrument, survey dispersion, data extraction and interpretation, statistical analysis, summarising and synthesising, manuscript preparation, revision, submission to journal.
Extent of contribution by PhD candidate (%)	95%

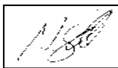
CO-AUTHORS

Name	Nature of Contribution
Beaven M.C.	Supervision, development of survey, revision, final manuscript revision
Gill N.D.	Supervision, development of survey, survey dispersion, revision, final manuscript revision
McMaster T.D.	Supervision, revision, final manuscript revision

Certification by Co-Authors

The undersigned hereby certify that:

❖ the above statement correctly reflects the nature and extent of the PhD candidate's contribution to this work, and the nature of the contribution of each of the co-authors; and

Name	Signature	Date
Beaven M.C.		21/11/2023
Gill N.D.		21/11/2023
McMaster T.D.		21/11/2023

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Please indicate the chapter/section/pages of this thesis that are extracted from a co-authored work and give the title and publication details or details of submission of the co-authored work.

Chapter 7: The influence of small-sided game design variables on the acute demands in rugby union youth
Wintershoven K., Beaven, M.C., Chan D.K.E., Gill, N.D., & McMaster T.D. The influence of elemental small-sided game design factors on kinematic, physiological, and physical performance markers in secondary school-level rugby union. Journal of Sport Sciences. (Under review).

Nature of contribution by PhD candidate	Development of the research question, literature review, participant sampling, data collection, data extraction and interpretation, statistical analysis, summarising and synthesising, manuscript preparation, revision, submission to journal.
Extent of contribution by PhD candidate (%)	90%

CO-AUTHORS

Name	Nature of Contribution
Beaven M.C.	Supervision, development of the research question, data collection, revision, final manuscript revision
Gill N.D.	Supervision, development of the research question, participant sampling, logistical support
Chan D.K.E.	Statistical support and revision of methods
McMaster T.D.	Supervision, revision, final manuscript revision

Certification by Co-Authors

The undersigned hereby certify that:

- the above statement correctly reflects the nature and extent of the PhD candidate's contribution to this work, and the nature of the contribution of each of the co-authors; and

Name	Signature	Date
Beaven M.C.		21/11/2023
Gill N.D.		21/11/2023
McMaster T.D.		21/11/2023
Chan D.K.E.		23/11/2023

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Please indicate the chapter/section/pages of this thesis that are extracted from a co-authored work and give the title and publication details or details of submission of the co-authored work.

Chapter 8: Match demands of youth rugby sevens
Wintershoven K., Beaven C.M., Gill N.D., & McMaster, T.D. New Zealand Youth Rugby Sevens: A Comparative Match Demands Study. *Journal of Functional Morphology and Kinesiology* 2023; 8: 41. DOI: 10.3390/jfmk8020041.

Nature of contribution by PhD candidate	Development of the research question, literature review, participant sampling, data collection, data extraction and interpretation, statistical analysis, summarising and synthesising, manuscript preparation, revision, submission to journal.
Extent of contribution by PhD candidate (%)	95%

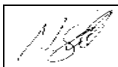
CO-AUTHORS

Name	Nature of Contribution
Beaven M.C	Supervision, revision, final manuscript revision
Gill N.D.	Supervision, participant sampling, logistical support, final manuscript revision
McMaster T.D.	Supervision, revision, final manuscript revision

Certification by Co-Authors

The undersigned hereby certify that:

- ❖ the above statement correctly reflects the nature and extent of the PhD candidate's contribution to this work, and the nature of the contribution of each of the co-authors; and

Name	Signature	Date
Beaven M.C		21/11/2023
Gill N.D.		21/11/2023
McMaster T.D.		21/11/2023

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Please indicate the chapter/section/pages of this thesis that are extracted from a co-authored work and give the title and publication details or details of submission of the co-authored work.

Chapter 9: Fifteen-a-side match demands of U19 rugby union players
Wintershoven K., Beaven M.C., Gill N.D., & McMaster T.D. New Zealand school-level rugby union match demands. Journal of Sport Sciences. (Submitted).

Nature of contribution by PhD candidate	Development of the research question, literature review, participant sampling, data collection, data extraction and interpretation, statistical analysis, summarising and synthesising, manuscript preparation, revision, submission to journal.
Extent of contribution by PhD candidate (%)	95%

CO-AUTHORS

Name	Nature of Contribution
Beaven M.C.	Supervision, revision, final manuscript revision
Gill N.D.	Supervision, participant sampling, logistical support
McMaster T.D.	Supervision, revision, final manuscript revision

Certification by Co-Authors

The undersigned hereby certify that:

- ❖ the above statement correctly reflects the nature and extent of the PhD candidate's contribution to this work, and the nature of the contribution of each of the co-authors; and

Name	Signature	Date
Beaven M.C.	[signature]	21/11/2023
Gill N.D.	[signature]	21/11/2023
McMaster T.D.	[signature]	21/11/2023