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Human Kinetics
ORIGINAL INVESTIGATION

Quantifying Offense and Defense Workloads in Professional Rugby Union

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Purpose: Rugby union is a contact team sport demanding high levels of physical capacity, and understanding the match workloads can be useful to inform training. In this study, the factors influencing locomotion and contact workloads for offensive and defensive ball-in-play periods are quantified. ***Methods:*** Locomotion and contact metrics were collected from global positioning system units and videos for 31 professional players of a Super Rugby team across 14 games in the 2021 season. Data were analyzed with a generalized mixed-model procedure that included effects for type of play, playing position, match outcome, and ball-in-play time. Magnitudes were assessed with standardization, and evidence for substantial magnitudes was derived from sampling uncertainty. ***Results:*** When offense was compared to defense, most metrics showed decisively substantial increases (small-moderate) for forwards and backs. There was decisive evidence that locomotion metrics were substantially lower (large differences) and contact metrics were higher (very large differences) when comparing forwards to backs on offense and defense. When winning was compared to losing, there was good evidence that forwards experienced small increases in overall workload on defense, and backs experienced a small increase in high-speed running and a moderate decrease in contacts. Match-to-match changes associated with ball-in-play time, attributed to fatigue, were decisive (moderate-very large) across most metrics for forwards and backs in offense and defense. ***Conclusions:*** The increased locomotion and contact workloads in offensive periods and the differing physical requirements between positions and match outcomes for both types of play are novel findings that should aid practitioners in designing effective training.

Keywords: ball-in-play, contact, game analysis, global positioning system, locomotion

Rugby union is a skill-based contact team sport that demands high levels of physical and tactical skill.[1] High-intensity activities can include many acceleration and deceleration events applied in multiple directions, such as contacts with opposition players during a tackle.[2] Movement and contact data from matches can allow coaches greater insight into the external demands during a game, which can be useful to prescribe training sessions for increased performance.[3]

In previous studies, time–motion analysis has been used to quantify workload into categories of intensity.[3] The validity of time–motion analysis for locomotion is questionable, as movement patterns are simplified into categories where actual play involves the dynamic combination of several tasks, skills, and tactics.[4] To quantify locomotion workloads more accurately, researchers have utilized global positioning systems (GPS).[5] Owing to the large amount of contact workload that occurs throughout the match, the use of locomotion metrics alone cannot quantify overall workload. Several events that players experience during the match are physically demanding, yet do not register a locomotive load, such as scrums, tackles, and lineouts. Although microtechnology accelerometers can detect up to 97% of collisions,[6] they are unable to distinguish between type and force of contact, 2 critical factors when analyzing game-specific situations.[7] These limitations have led many researchers to focus solely on locomotion (GPS) data when assessing high-intensity exercise, despite the obvious physical demands of contact events.[8] Complete analysis of match workload currently requires the pairing of GPS data and the manual quantification of contact events through video analysis.[7]

Although a rugby match is designed to last for 80 minutes, players are typically subjected to only approximately 30 minutes of live play (referred to as ball-in-play).[4] Researchers have utilized ball-in-play analysis to exclude the 60% to 70% of data collected during periods of the game where the ball is out of play (and thus little to no work is occurring).[9] Ball-in-play analyses have reported greater peak in-play match demands compared to other methods, such as the fixed-time or rolling methodology, as these utilize fixed-time intervals which can include or intersect work and rest intervals of varying duration.[9] However, there is potential to segment the match further to develop an even greater understanding of situational workload, such as splitting ball-in-play into offensive and defensive periods. Understanding the external demands of these periods could be useful to replicate match workloads during training and provide further insight into player load and fatigue.[10] To our knowledge, the research in this area in rugby union is limited to levels below professional. Therefore, the aim of the current study was to compare the workloads of offensive and defensive ball-in-play periods of professional rugby union match-play by evaluating selected GPS locomotion measures and quantifying contact metrics.

Methods

Subjects

GPS and contact data were collected from 31 professional male rugby union players from one New Zealand Super Rugby team (age: 25.0 [3.3] y; height 187.6 [6.9] cm, body mass 108.2 Q4

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[12.4] kg). The study protocol was approved by the Human Ethics Committee of the University of Waikato, New Zealand. Informed consent forms were signed by all participants before the commencement of this study. Throughout this study, all participants were injury-free and in full-time training. Participants were familiarized with the data collection procedures prior to commencement and not required to make changes to their regular competition and training for the duration of our study.

Design

Data were collected during 14 in-season games of the 2021 Super Rugby season. Participants were grouped into the following positions: Forwards (props, hooker, second row, loose forwards) and backs (midfield backs, inside backs, and outside backs). Each match was divided into offensive and defensive periods using the criteria set in Supplementary Material S7 (available online). Data were analyzed with a generalized mixed-model procedure that included effects for type of play (offense, defense), playing position (forwards, backs), match outcome (win, loss), and ball-in-play time. Magnitudes were assessed with standardization, and evidence for substantial magnitudes was derived from sampling uncertainty.

Methodology

All participants wore GPS units (Apex Pro Pod, STATSport) which collected data at a sampling frequency of 10 Hz. Data were collected and analyzed for all players on the field irrespective of their total playing time. The mean recorded horizontal dilation of precision and number of connected satellites for all data were 1.73 (3.13) and 15 (5.06), respectively. Before the prematch warm-up, GPS units were switched on and activated as per the manufacturer's guidelines. Devices were placed between the scapulae in a tightly-fitting vest, and participants wore the same GPS unit for each match to minimize interunit variability. Data were downloaded using STATSports Sonra software (STATSports Sonra).

Match footage obtained from the broadcast provider was downloaded into the Sportscode video analysis software package (Sportscode 12.4.3, Sportstec). Events were manually coded using criteria set in Supplementary Material S7 (available online), these being: Ball out of play, offensive ball-in-play periods, defensive ball-in-play periods, and a selection of contact metrics. Each contact instance was categorized into one of 3 weighted efforts: minimal, hard, or maximal, corresponding to weighting values of 1, 3, and 5, respectively, based on the criteria set in Supplementary Material S7 (available online). Weightings were selected as derivatives of the Borg CR10 RPE scale descriptors.[11] The resulting events in Sportscode were a combination of the type of contact and the contact weighting (eg, tackle, hard), recorded as a weighted count.

The full-match video file was imported into STATSports Sonra software and aligned to the GPS data. GPS data were segmented into ball out of play periods, offensive ball-in-play periods, and defensive ball-in-play periods, using the Sportscode XML file created prior. GPS data were then exported as a CSV file, showing key metrics for each period. The GPS metrics chosen for analysis were based on locomotion metrics previously examined in the literature for rugby union and are detailed in Supplementary Material S8 (available online).

Data were combined and aligned using SportyWeb sports analytics software (SportyWeb, version 1.0, SportyWeb Analytics). Once the data sets were aligned, a CSV file was exported with the offense periods, defense periods, and corresponding GPS and contact metric values for each player within each period. Match outcome and end-of-season opposition rank were manually added to this file.

Statistical Analysis

All data were analyzed with the Statistical Analysis System (On-Demand for Academics, version 9.04, SAS Institute Inc). Player metrics were either counts (accelerations and decelerations), counts weighted by distance (high-velocity distance, high-metabolic load distance, high-speed running distance, very-high metabolic load distance, sprint distance, and total distance), or counts weighted by other factors (contacts and dynamic stress load). These metrics were analyzed with a generalized linear mixed-model procedure (Proc Glimmix) specifying a log link and a Poisson distribution that allowed for overdispersion. Each player metric was analyzed separately with the same mixed model. The fixed effects in the model were: player position (nominal: backs, forwards); type of play (nominal: defense, offense); the interaction of player position and type of play; match outcome (nominal: loss, win); the interaction of match outcome, player position, and type of play; end-of-season opposition ranking (linear numeric); round of the match (linear numeric); and the log of ball-in-play time (linear numeric) interacted with player position and type of play. The predicted means for the different levels of the nominal predictors were adjusted to mean opposition rank, the middle round of the season, and the grand mean of time spent in each type of play across all matches and players. The linearity of each numeric predictor was assessed by visual inspection of plots of standardized residuals versus the predictor for any nonuniformity.

The random effects in the model were: player identity (nominal) to estimate differences between player means; the interaction of player identity with log of ball-in-play time to estimate individual differences in the effect of time; match identity (nominal) to estimate differences between match means; the interaction between player identity and match identity to estimate each player's mean change of defense and offense between matches; and the residual, specified as a Poisson variance, allowing for overdispersion or underdispersion. The covariance matrix for player identity and its interaction with time was set to unstructured to allow the solutions for these random effects to be correlated (a random intercepts and slopes model).

The following outcomes derived from the fixed effects were expressed as factors with 90% factor confidence limits: the difference between means of player positions; the change between the means of defense and offense; the changes between the means for losing and winning; the change between the means when playing the weakest versus the strongest opposition team; the changes between the means for the first and last match of the season; and the relationship between player metrics and player time on offense or defense was expressed as the slope (coefficient, in %/% units) of ball-in-play time. A measure of fatigue was also calculated from the coefficient for ball-in-play time as the factor difference between the mean value predicted for the mean time on the field versus the predicted mean for a 1:1 linear relationship between the metric and time on field. The SDs representing differences between player means (from the random effect for player identity) and individual differences in fatigue (from the interaction of player identity with ball-in-play time) were also expressed as factors and assessed for magnitude.

The magnitudes of outcomes derived from fixed effects were assessed with thresholds set at 0.2, 0.6, 1.2, 2.0, and 4.0 of the log-transformed observed between-player SD,[12] corresponding to small, moderate, large, very large, and extremely large qualitative effect sizes, respectively (Supplementary Material S1 [available online]); the magnitude thresholds for the SDs were half these values[13] (Supplementary Material S2 [available online]). Sampling uncertainty in the estimates of effects is presented as 90% confidence limits. Decisions about magnitudes accounting for the uncertainty were based on one-sided interval hypothesis tests.[14] For details, see Supplementary Material S9 (available online).

Results

Match and player summary data are shown in Table 1. The order of the metrics in the subsequent tables were determined by the correlations between the metrics, with the expectation that highly correlated metrics will have similar effects. Correlations and clustering of metrics are presented in Supplementary Material S3 (available online), where clusters of metrics have been identified as those with high correlations (>.60) between metrics within clusters and low correlations (<.60) between metrics between clusters.

Metric mean values for each combination of position and type of play and metric SDs are reported in Table 2. The means and SDs are derived from the mixed model and therefore represent values after adjustment for the fixed and random effects in the model. The player observed between SD is the typical difference between players in a given position and type of play in a typical match; it is the combination of the within-match player SD (the residual in the model, the Poisson variability), the pure between-player SD (the typical difference between player means over the season), and the player match-to-match SD (the typical change in the mean of a player's offense and defense values between matches). The pure between-player SD has a practical application, describing the extent to which values varied between players for each metric (shown in greater detail in Supplementary Material S4 [available online]). Notably, the sprint metric had the largest effect, indicating that this metric varies the most between players. The match SD is a pure representation of the typical difference between the match means. The differences between means apparent in Table 2 are detailed in Table 3. For most measures, the observed between-player SD arises mainly from the random Poisson variation, and (with one exception) there is no contribution from consistent

Table 1 Match and Player Summary Data

	Team	Forwards	Backs
Players, n	31	19	12
Mean age, y	25.0 (3.3)	25.8 (3.1)	23.7 (3.1)
Mean height, cm	187.6 (6.9)	188.7 (7.3)	185.9 (6.1)
Mean body mass, kg	108.2 (12.4)	115.2 (9.1)	97.3 (8.7)
Matches, n	14	14	14
Mean matches (n) per player	8.3 (4.2)	8.3 (3.8)	8.3 (4.5)
Player-matches, n	257	157	100
Player mean match BIP time	20.2 (9.5)	18.7 (8.9)	22.6 (10.1)
Player mean match BIP time—offense	10.6 (5.2)	7.6 (3.5)	9.9 (4.1)
Player mean match BIP time—defense	9.6 (4.6)	8.4 (3.7)	10.7 (5.0)

Abbreviation: BIP, ball-in-play.

Table 2 Player Values (Means and Factor SDs) and Differences Between Matches (Match SD) Provided by the Poisson-Regression Analysis for Each Player Metric

	Player means				Player factor SDs (×/÷)				
	Fwds offense	Fwds defense	Backs offense	Backs defense	Observed btwn	Within-match	Pure btwn	Match-match	Match SD (×/÷)
HiVel, m	257	209	457	360	1.48	1.38	1.24	1.00	1.09
HMLD, m	239	198	410	332	1.43	1.34	1.22	1.00	1.05
HSR, m	59	36	188	136	1.93	1.61	1.57	1.00	1.14
VHMLD, m	49	37	128	104	1.73	1.49	1.45	1.00	1.03
Sprint, m	3	2	46	27	3.93	2.78	2.49	1.18	1.30
Distance, m	1039	923	1189	998	1.31	1.30	1.06	1.00	1.01
Contacts	83	58	28	20	1.50	1.49	1.10	1.00	1.03
Accelerations	34	34	39	36	1.40	1.34	1.17	1.00	1.00
Decelerations	30	28	30	30	1.47	1.41	1.18	1.00	1.00
DSL	90	77	91	65	1.64	1.40	1.44	1.00	1.04

Abbreviations: btwn, between players; Distance, total distance; DSL, dynamic stress load; Fwds, forwards; HiVel, high-velocity distance; HMLD, high-metabolic load distance; HSR, high-speed running distance; Sprint, sprint distance; VHMLD, very-high metabolic load distance. Note: Contacts and DSL are weighted counts; accelerations and decelerations are counts. Values have been adjusted to the grand mean ball-in-play time of 8.5 minutes for offense and defense. This value may be used for the calculation of metrics per minute.

Table 3 Differences Between Means for Forwards and Backs on Offense Versus Defense Expressed as Factor Effects and Effect Sizes

	Factor effect	Effect size
Forwards—offense vs defense		
HiVel	1.23, ×/÷1.08	**Small↑*****
HMLD	1.21, ×/÷1.07	**Small↑******
HSR	1.62, ×/÷1.15	**Moderate↑******
VHMLD	1.32, ×/÷1.11	**Small↑*****
Sprint	1.39, ×/÷1.41	Small↑*^{0}
Distance	1.13, ×/÷1.06	**Small↑*****
Contacts	1.44, ×/÷1.07	**Moderate↑******
Accelerations	0.99, ×/÷1.07	Trivial^{00}
Decelerations	1.08, ×/÷1.08	**Trivial↑^{0}***
DSL	1.17, ×/÷1.07	**Small↑****
Backs—offense vs defense		
HiVel	1.27, ×/÷1.08	**Moderate↑******
HMLD	1.24, ×/÷1.08	**Small↑******
HSR	1.39, ×/÷1.11	**Small↑******
VHMLD	1.22, ×/÷1.10	**Small↑****
Sprint	1.75, ×/÷1.18	**Small↑*****
Distance	1.19, ×/÷1.08	**Moderate↑******
Contacts	1.43, ×/÷1.16	**Moderate↑******
Accelerations	1.07, ×/÷1.09	**Trivial↑^{0}***
Decelerations	1.00, ×/÷1.10	Trivial
DSL	1.40, ×/÷1.10	**Moderate↑******
Offense—forwards vs backs		
HiVel	0.56, ×/÷1.17	**Large↓******
HMLD	0.58, ×/÷1.16	**Large↓******
HSR	0.31, ×/÷1.35	**Large↓******
VHMLD	0.38, ×/÷1.29	**Large↓******
Sprint	0.07, ×/÷1.90	**Large↓******
Distance	0.87, ×/÷1.08	**Small↓*****
Contacts	2.96, ×/÷1.14	**Very large↑******
Accelerations	0.87, ×/÷1.14	**Small↓****
Decelerations	1.01, ×/÷1.15	Trivial
DSL	0.99, ×/÷1.28	Trivial
Defense—forwards vs backs		
HiVel	0.58, ×/÷1.18	**Large↓******
HMLD	0.60, ×/÷1.17	**Large↓******
HSR	0.27, ×/÷1.37	**Large↓******
VHMLD	0.35, ×/÷1.30	**Large↓******
Sprint	0.09, ×/1.94	**Large↓******
Distance	0.93, ×/÷1.08	**Small↓*^{0}**
Contacts	2.92, ×/÷1.16	**Very large↑******
Accelerations	0.93, ×/÷1.14	Small↓*^{0}
Decelerations	0.94, ×/÷1.15	Trivial
DSL	1.18, ×/÷1.28	Small↑*^{0}

Abbreviations: Distance, total distance; DSL, dynamic stress load; HiVel, high-velocity distance; HMLD, high-metabolic load distance; HSR, high-speed running distance; Sprint, sprint distance; VHMLD, very-high metabolic load distance. Note: Uncertainty in effects is shown as factor (×/÷) 90% confidence limits. Magnitudes were assessed by standardization using the observed between-player SD (Table 2 and Supplementary Material S1 [available online]). Likelihoods are not shown for effects with inadequate precision at the 90% level (failure to reject any hypotheses: $P < .05$). Magnitudes in bold have acceptable precision with 99% confidence limits.
Bayesian likelihoods of substantial difference: *possibly; **likely; ***very likely; ****most likely. *** and **** indicate rejection of the nonsuperiority or noninferiority hypothesis ($p_{N\downarrow}$ or $p_{N\uparrow} < 0.05$ and < 0.005, respectively). Bayesian likelihoods of trivial change: ^{0}possibly; ^{00}likely. ↑ and ↓ indicate a substantial increase and decrease.

match-to-match variation (player match-to-match factor SD of 1.00). The values for match SD in the table show that there are real differences between match means for most metrics, but these are much less than the observed differences between players.

Effects comparing each position and type of play for each metric are presented in Table 3. Small to moderate increases were observed for the majority of metrics between offense and defense, for both forwards and backs. Most of these effects had adequate precision at the 99% level for true magnitudes to be considered very likely or most likely substantial. When comparing forwards to backs, most metrics, particularly those of a locomotive nature, were lower (large differences) for forwards than backs across both offense and defense, with sufficient precision at the 99% level for the true magnitudes to be deemed most likely substantial. Conversely, contacts were higher (very large differences) when comparing forwards to backs for both offensive and defensive periods of play.

The observed metric changes between winning and losing shown in Table 4 were mostly trivial but lacked adequate precision for forwards on offense and backs on defense. Small effects were observed for some metrics for forwards on defense, typically tending to increase when the match outcome was winning compared to losing. Some of these changes had adequate precision at the 99% level, but at most, they were only likely substantial. The effects with the most likelihood of being substantial were for backs on offense, with small to moderate increases or decreases observed for most metrics.

The effect on each metric of player time on the field is expressed in Table 5 as %/% units, and as a factor effect, with values below 1.00 representing fatigue. Fatigue effects are equivalent to a decrease in metric value per minute. The between-player SD for each metric is also shown, representing the individual differences between players in fatigue. For the majority of the metrics, the magnitude of fatigue was large or very large for forwards on offense and defense, and for backs on defense, with sufficient precision at the 99% level for true magnitudes to be most likely substantial. Fatigue was less clear for backs on offense, with most magnitudes of fatigue being moderate or large, with some effects having adequate precision only at the 90% level and with one effect being unclear. The individual differences in fatigue ranged from trivial to very large, but there was adequate precision only for contacts and only at the 90% level.

Data are not shown in tables for the effects of opposition ranking and season trend. The majority of observed effects for opposition ranking were trivial, several with inadequate precision. Many showed a possibility of a small increase when playing the weakest versus the strongest team (rank 10 vs 2), but only 2 had adequate precision at the 99% level: a small, possibly substantial, possibly trivial increase for accelerations; and a trivial, possibly substantial increase for very-high metabolic load distance. Season

Table 4 Differences Between Means for Winning Versus Losing for Forwards on Offence and Defense, Expressed as Factor Effects and Effect Sizes

	Factor effect	Effect size
Forwards offense—win vs loss		
HiVel	1.10, ×/÷1.16	Small↑*^{0}
HMLD	1.02, ×/÷1.12	Trivial
HSR	1.11, ×/÷1.25	Trivial↑^{0}*
VHMLD	1.00, ×/÷1.15	Trivial
Sprint	0.96, ×/÷1.61	Trivial
Distance	0.97, ×/÷1.09	Trivial
Contacts	1.04, ×/÷1.10	Trivial↑^{0}*
Accelerations	0.91, ×/÷1.10	**Small↓*^{0}**
Decelerations	0.93, ×/÷1.11	Trivial↓^{0}*
DSL	0.91, ×/÷1.11	**Trivial↓^{0}***
Forwards defense—win vs loss		
HiVel	1.18, ×/÷1.16	**Small↑****
HMLD	1.13, ×/÷1.12	**Small↑****
HSR	0.95, ×/÷1.27	Trivial
VHMLD	1.07, ×/÷1.17	Trivial↑^{0}*
Sprint	0.65, ×/÷1.64	Small↓*^{0}
Distance	1.09, ×/÷1.09	**Small↑*^{0}**
Contacts	1.09, ×/÷1.11	**Small↑*^{0}**
Accelerations	1.09, ×/÷1.19	**Small↑*^{0}**
Decelerations	1.07, ×/÷1.11	Trivial↑^{0}*
DSL	1.04, ×/÷1.12	Trivial^{00}
Backs defense—win vs loss		
HiVel	1.10, ×/÷1.15	Small↑*^{0}
HMLD	1.04, ×/÷1.11	Trivial↑^{0}*
HSR	1.40, ×/÷1.21	**Small↑*****
VHMLD	1.08, ×/÷1.12	**Trivial↑^{0}***
Sprint	1.59, ×/÷1.42	**Small↑****
Distance	0.96, ×/÷1.09	Trivial↓^{0}*
Contacts	0.69, ×/÷1.18	**Moderate↓******
Accelerations	0.83, ×/÷1.11	**Small↓*****
Decelerations	0.80, ×/÷1.13	**Small↓*****
DSL	0.82, ×/÷1.12	**Small↓****
Backs defense—win vs loss		
HiVel	1.04, ×/÷1.15	Trivial
HMLD	1.02, ×/÷1.12	Trivial
HSR	0.99, ×/÷1.22	Trivial
VHMLD	0.96, ×/÷1.13	Trivial^{00}
Sprint	0.78, ×/÷1.45	Trivial↓^{0}*
Distance	1.06, ×/÷1.10	Small↑*^{0}
Contacts	0.99, ×/÷1.23	Trivial
Accelerations	0.98, ×/÷1.11	Trivial
Decelerations	0.97, ×/÷1.13	Trivial
DSL	1.04, ×/÷1.14	Trivial^{00}

Abbreviations: Distance, total distance; DSL, dynamic stress load; HiVel, high-velocity distance; HMLD, high-metabolic load distance; HSR, high-speed running distance; Sprint, sprint distance; VHMLD, very-high metabolic load distance. Note: Uncertainty in effects is shown as factor (×/÷) 90% confidence limits. Magnitudes were assessed by standardization using the observed between-player SD (Table 2 and Supplementary Material S1 [available online]). Likelihoods are not shown for effects with inadequate precision at the 90% level (failure to reject any hypotheses: $P < .05$). Magnitudes in bold have acceptable precision with 99% confidence limits.

Bayesian likelihoods of substantial difference: *possibly; **likely; ***very likely; ****most likely. *** and **** indicate rejection of the nonsuperiority or noninferiority hypothesis ($p_{N\downarrow}$ or $p_{N\uparrow} < 0.05$ and < 0.005, respectively). Bayesian likelihoods of trivial change: ^{0}possibly; ^{00}likely. ↑ and ↓ indicate a substantial increase and decrease.

trend showed a number of small effects, the majority with adequate precision at the 99% level; there were increases for contacts (possibly), accelerations (likely), and decelerations (likely), while there were decreases for high-metabolic load distance and very-high metabolic load distance (possibly), sprint distance and high-velocity distance (likely), and high-speed running (most likely).

Discussion

The aim of this study was to compare the workloads of offensive and defensive periods of professional rugby union match play. The majority of metrics showed greater values in offensive periods, suggesting increased external demands when compared to defensive periods. For locomotion metrics, one potential reason for the decisively lesser workload on defense compared to offense is more time is spent moving backwards on defense while facing the opposition, which restricts the capacity to achieve high velocities. At identical GPS velocities, running backward (or sideways) may require greater energy expenditure than running forward. Consequently, GPS derived external demands may underestimate the true (internal) physiological demands during defensive periods of play. Read et al[10] presented the only research directly comparable to the current study, with positional workload examined for offense and defense in rugby union. They reported no substantial difference in distance per minute and player-load per minute for forwards on offense compared to defense, while backs showed a likely greater difference in distance per minute and player-load per minute on offense when compared to defense. This study was conducted on academy-level players, so it may not provide a direct comparison to professional rugby union.

The results of the current study indicate decisive differences in most metrics between forwards and backs in offense and defense. In particular, backs experienced greater locomotive measures, while forwards had a greater contact load. Similar effects have been observed in numerous previous studies.[1–4,9,15,16] While most differences for locomotion metrics were most likely large, the difference in total distance between forwards and backs was likely small on offense and possibly small on defense, suggesting that backs covered a similar distance to forwards but at higher intensities. It has been suggested that this is due to forwards being in close proximity to the opposition, while backs have more space to achieve greater running velocities.[2,3,9] Pollard et al[9] reported trivial differences in acceleration and deceleration metrics between forwards and backs, explaining that forwards, despite not having space to achieve high velocities, were still required to perform multiple short accelerations and decelerations. This explanation may apply to our own study, where the differences for these metrics

Table 5 The Effect of Player Time on the Field on Each Metric for Forwards in Offence and Defense

		Fatigue	
	Slope, %/%	Factor effect	Effect size
Forwards offence			
HiVel	0.73, ±0.11	0.57, ×/÷1.24	**Large↓******
HMLD	0.67, ±0.11	0.51, ×/÷1.24	**Large↓******
HSR	0.84, ±0.17	0.71, ×/÷1.40	Small↓**
VHMLD	0.58, ±0.16	0.43, ×/÷1.37	**Large↓******
Sprint	1.14, ±0.47	1.32, ×/÷2.58	Small↑
Distance	0.81, ±0.08	0.67, ×/÷1.17	**Large↓******
Contacts	0.63, ±0.12	0.47, ×/÷1.28	**Large↓******
Accelerations	0.61, ±0.10	0.45, ×/÷1.23	**Very large↓******
Decelerations	0.59, ±0.11	0.43, ×/÷1.26	**Very large↓******
DSL	0.64, ±0.12	0.48, ×/÷1.26	**Large↓******
Forwards defense			
HiVel	0.75, ±0.11	0.58, ×/÷1.26	**Large↓******
HMLD	0.72, ±0.11	0.54, ×/÷1.26	**Large ↓******
HSR	1.04, ±0.21	1.09, ×/÷1.54	Trivial
VHMLD	0.76, ±0.17	0.59, ×/÷1.44	**Moderate↓*****
Sprint	1.21, ±0.52	1.53, ×/÷3.01	Small↑
Distance	0.78, ±0.08	0.62, ×/÷1.17	**Large↓******
Contacts	0.66, ±0.13	0.49, ×/÷1.31	**Large↓******
Accelerations	0.62, ±0.10	0.44, ×/÷1.24	**Very large↓******
Decelerations	0.63, ±0.12	0.46, ×/÷1.28	**Very large↓******
DSL	0.60, ±0.12	0.42, ×/÷1.28	**Large↓******
Backs offence			
HiVel	0.83, ±0.10	0.69, ×/÷1.24	**Moderate↓*****
HMLD	0.80, ±0.11	0.64, ×/÷1.27	**Large↓*****
HSR	0.81, ±0.13	0.65, ×/÷1.32	**Moderate↓*****
VHMLD	0.82, ±0.16	0.67, ×/÷1.41	Moderate↓**
Sprint	0.81, ±0.25	0.65, ×/÷1.71	Small↓*^{0}
Distance	0.86, ±0.09	0.72, ×/÷1.21	**Moderate↓*****
Contacts	0.86, ±0.21	0.72, ×/÷1.59	Moderate↓
Accelerations	0.78, ±0.13	0.60, ×/÷1.32	**Large↓*****
Decelerations	0.76, ±0.15	0.58, ×/÷1.38	**Large↓*****
DSL	0.84, ±0.15	0.69, ×/÷1.38	Moderate↓**
Backs defense			
HiVel	0.67, ±0.10	0.49, ×/÷1.23	**Large↓******
HMLD	0.65, ±0.11	0.47, ×/÷1.26	**Very large↓******
HSR	0.46, ±0.13	0.32, ×/÷1.31	**Large↓******
VHMLD	0.54, ±0.15	0.38, ×/÷1.38	**Large↓******
Sprint	0.31, ±0.24	0.23, ×/÷1.67	**Moderate↓*****
Distance	0.83, ±0.09	0.57, ×/÷1.20	**Very large↓******
Contacts	0.46, ±0.21	0.32, ×/÷1.55	**Very large↓******
Accelerations	0.71, ±0.12	0.53, ×/÷1.29	**Large↓******
Decelerations	0.69, ±0.14	0.51, ×/÷1.33	**Large↓******
DSL	0.70, ±0.15	0.52, ×/÷1.38	**Large↓******

(continued)

Table 5 *(continued)*

Abbreviations: Distance, total distance; DSL, dynamic stress load; HiVel, high-velocity distance; HMLD, high-metabolic load distance; HSR, high-speed running distance; Sprint, sprint distance; VHMLD, very-high metabolic load distance. Note: The effect is expressed as the slope (coefficient) of time in the Poisson-regression model (in %/% units), and as fatigue, calculated at the factor reduction in the given metric from the predicted 1:1 linear value after the mean time on the field. Magnitudes were assessed by standardization using the observed between-player SD (Table 2 and Supplementary Material S1 [available online]). Likelihoods are not shown for effects with inadequate precision at the 90% level (failure to reject any hypotheses: $P < .05$). Magnitudes in bold have acceptable precision with 99% confidence limits.

Bayesian likelihoods of substantial difference: *possibly; **likely; ***very likely; ****most likely. *** and **** indicate rejection of the nonsuperiority or noninferiority hypothesis ($p_{N\downarrow}$ or $p_{N\uparrow} < 0.05$ and < 0.005, respectively). Bayesian likelihoods of trivial change: ^{0}possibly. ↑ and ↓ indicate a substantial increase and decrease.

were likely small at most. The locomotion metrics alone would suggest that backs are subject to greater external demands than forwards in both offense and defense. For example, the movements that are frequent with high-metabolic load distance have been associated with greater loading and fatiguing effects and linked to a greater risk of injury.[17] However, GPS measurements cannot realistically capture the complete external demands that players experience during the match, as several activities such as contacts are physically demanding yet do not register a locomotive load. Smart et al[18] observed that changes in creatine kinase levels measured postmatch could largely be explained by physical impacts, and these changes were significantly greater for forwards compared to backs. The decisively greater contact demands of forwards compared to backs during offense and defense observed in the current study must therefore be taken into account when assessing total load and fatigue, although direct comparisons to locomotion metrics are difficult and present a subject of future research.

When winning was compared to losing, there was very good evidence that backs achieved greater high-speed running distance on offense and modest or good evidence for greater values of other locomotion metrics. The differences between winning and losing lacked adequate precision for most metrics for backs on defense. When paired with the decisively greater workload requirements of backs on offense compared with defense, these effects are perhaps indicative of the importance of greater involvement of backs during offensive periods, particularly when it comes to measures of running intensity. There was also very good evidence that backs experienced fewer contacts, accelerations, and decelerations on offense when winning was compared to losing. One possible explanation is that the backs of a winning team evade contacts on offense and thereby achieve more successful advances against the opposition. In our experience, accelerations above 2 $m{\cdot}s^{-2}$ are easier to achieve from a stationary position; therefore, lower counts of accelerations and decelerations on offense could indicate fewer "stop/start" periods as the opposition is making fewer tackles and not halting the advancing play. Missed tackles have been shown to be linked to unsuccessful match outcomes in previous literature.[19] In contrast to backs, forwards were inclined to experience slightly greater workloads during defense when the match outcome resulted in a win. High-velocity distance, high-metabolic load distance, accelerations, and contacts showed possibly or likely small increases for forwards on defense when winning was compared to losing, while differences on offense were mostly unclear or trivial. Despite decisive evidence of overall greater workloads for most metrics during offense, this finding is perhaps indicative of the importance of defensive efforts by the forwards. One possible explanation is that if forwards covered more distance at a greater intensity and had more contacts during defense, they were likely stopping the opposing team's offense more successfully. If the forwards were producing greater overall workloads on defense, the likelihood of winning might have been higher as the offense of the opposing team could not break through the forwards' line as often, which must be achieved in order to score. These findings align with those of Scott et al,[19] who found that collision dominance allowed teams to increase relative meterage, which in turn was associated with match success.

There was decisive evidence of player fatigue for most metrics for forwards and backs in offense and defense. This is unsurprising, as the longer a player is on the field, the more the metrics would be expected to decline due to match demands.[9] Interestingly, the fatigue effects for backs tended to have greater magnitudes for defense than offense, even though backs experienced greater workloads across most metrics in offense. Backs were less involved physically in defensive plays and perhaps were consequently able to take more time to rest during these periods as the match progressed and players fatigued. Such a strategy could allow for greater intensities to be achieved during offensive plays, when the backs' involvement appeared to be more prominent (in terms of workload) and more important (in terms of winning). The magnitudes of fatigue for forwards were similar between offensive and defensive periods, despite intensities being, in general, decisively greater on offence.

The current investigation includes a novel method of quantifying nonlocomotive and contact workload. This approach seeks to resolve the limitation described by Cummins et al,[7] whereby current methodologies are unable to distinguish between the type and force of contact. Although further validation of this method is required, the authors suggest it is a step toward a more accurate quantification of nonlocomotive workload that provides additional insight when compared to (or combined with) accelerometer data and an evolution of current time–motion techniques. Supplementary Material S6 (available online) depicts the frequency of each type of contact for forwards and backs in offense and defense, along with their corresponding weighting. Practitioners may use this information to achieve or exceed these values in training. Values are player-counts and therefore reflect when multiple players are involved in a single event (eg, 1 scrum would record 8 player-counts), as opposed to the count of the events themselves. As data in this table has not been adjusted in the model, it does not account for ethics omissions and may therefore underestimate true match values by ~10%. Values are also not adjusted for the number of players in each position or ball-in-play time for each type of play, and are therefore not appropriate for comparisons between positions or type of play. Referring to ball-in-play time for offense and defense (Table 1) will allow practitioners to calculate these metrics per minute.

Practical Applications

Offensive periods of play demanded a decisively greater workload than defensive periods of play for forwards and backs across most metrics, suggesting that offensive is more externally demanding than defense. This finding should aid practitioners in designing protocols that reflect demands for these types of play. The decisive evidence that backs performed greater locomotion but less contact workload compared to forwards in both offense and defense is consistent with previous literature, and reinforces the importance of position-specific preparation. Although the greater locomotion of backs is suggestive of greater external demands, it is important to consider contact events (of which forwards experience decisively more) when assessing overall load and fatigue. When winning was compared to losing, there was good evidence that backs achieved greater values for most locomotion metrics on offense, while forwards achieved greater overall workloads during defense. Practitioners may use this information to emphasize specific aspects of training in order to implement outcome-oriented conditioning for each position and type of play. A limitation of the current study is that only a single team and season were analyzed. Results are, therefore, inclined to reflect the strategic and conditioning practices of this team and season. The authors recognize that although including all players on the field for analysis (irrespective of total playing time) reflects the authentic match demands that occurred, this methodology can also lead to overestimation of per minute values and underestimation of absolute values typically expected for players. Researchers in the future should aim to more accurately quantify locomotion workload by examining the demands of different modes of movement, such as sideways and backwards running. In addition, conclusions with regard to match outcome should be interpreted with caution. Although winning is the ultimate goal for players and practitioners alike, and therefore is relevant to include for analysis, it is difficult to draw causality between the reported metrics and the outcome, as a win or loss cannot be so easily derived without considering a large number of additional variables at play. In the future, authors may wish to investigate the relationship between similar metrics and proxies of match performance where direct relationships may be easier to define.

Conclusions

To our knowledge, this is the first detailed study of offensive and defensive ball-in-play workload for professional rugby union. Differing locomotion and contact demands were shown when comparing type of play (offense vs defense), player position (forwards vs backs), match outcome (winning vs losing), and ball-in-play time, forming novel findings that should aid practitioners in preparing players for specific aspects of the game.

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Queries

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