



THE UNIVERSITY OF
WAIKATO
Te Whare Wānanga o Waikato

Research Commons

<http://researchcommons.waikato.ac.nz/>

Research Commons at the University of Waikato

Copyright Statement:

The digital copy of this thesis is protected by the Copyright Act 1994 (New Zealand).

The thesis may be consulted by you, provided you comply with the provisions of the Act and the following conditions of use:

- Any use you make of these documents or images must be for research or private study purposes only, and you may not make them available to any other person.
- Authors control the copyright of their thesis. You will recognise the author's right to be identified as the author of the thesis, and due acknowledgement will be made to the author where appropriate.
- You will obtain the author's permission before publishing any material from the thesis.

**The use of compression garments for recovery following
team-sport exercise**

A thesis submitted in partial fulfillment
of the requirements for the degree
of
Master of Health, Sport and Human Performance
at
The University of Waikato
by
Rebecca Atkins



THE UNIVERSITY OF
WAIKATO
Te Whare Wānanga o Waikato

2019

Abstract

Recovery interventions are constantly being sought after and investigated to determine which method is the most beneficial for exercise recovery. Some athletes (e.g. basketball) must prepare for events such as 3-5 day tournaments; during these types of tournaments, there is a short turn around between games, often having to play multiple games within a 24h period (e.g. two games on the same day or one at night and one in the morning). The short turn around presents a limited time for recovery, which means interventions are often implemented to assist in expediting the recovery rate. The use of compression garments following exercise has been said to increase the rate of recovery by increasing blood flow, reducing space for swelling and reducing levels of muscle damage and inflammatory markers. Research has been performed in different sports and for different time frames when wearing compression garments following exercise. This thesis will firstly review the current literature on compression garments used for recovery in the sport setting and identify the gaps in the literature. The thesis then includes an experimental study in chapter 2, which investigates the effects of compression garments (full length, lower-limb) worn overnight (approx. 15 hours) on markers of recovery, in an attempt to fill some of the gaps highlighted in the literature review.

The experimental study in this thesis included a parallel-group design, where 30 male basketball athletes (mean \pm SD age: 23 \pm 4 years) were allocated to either a control group (participants wore loose-fitted clothing following exercise) or an experimental group (participants wore lower-limb compression garments following exercise). An exercise session including basketball specific movements was used to induce physical fatigue. Physical tests (countermovement jump, 20m repeated sprints and 5-0-5 agility

tests) and perceptual measures (fatigue and muscle soreness) were conducted pre-exercise, post-exercise and the following morning 15h post-exercise. Perceived and actual sleep measures were recorded during the overnight stay in the laboratory. The main result found in the original study was the perceptual ratings of muscle soreness and fatigue. The results were in favour of the compression garments group with *large* differences ($d = -1.27$ and $d = -1.61$ respectively) and significant improvement ($p = 0.04$) compared to a control group. This thesis adds knowledge to the existing literature on compression garment use for recovery in a team sport, reporting the limitations, practical implications and future research directions for compression garment in recovery.

Acknowledgements

Firstly I would like to acknowledge my primary supervisor Dr. Matthew Driller for your guidance and knowledge and never giving up on me. I will be forever grateful for your never-ending support and encouragement.

Secondly to my family and friends for always pushing me to achieve my best and encouraging me to keep going, also for cooking for me when I was too busy. Especially my sister who gave me the push to complete my study and never settles for anything just the way it is.

Lastly to Dr. Gilbert Lam for providing the opportunity to conduct the study and everyone who has helped along the way.

Table of Contents

Abstract.....	ii
Acknowledgements	iv
List of Figures.....	vi
List of Tables	vi
Abbreviations	vii
Thesis Overview	viii
Chapter 1: Literature Review.....	1
Compression garments overview.....	2
Characteristics of compression garments.....	3
Physiological effects of compression garments	5
Performance effects of compression garments.....	9
Psychological effects of compression garments.....	15
Compression garments in basketball	20
Conclusion	22
Chapter 2: Lower-body compression garments worn following exercise improves perceived recovery but not subsequent performance in basketball athletes	23
Abstract.....	24
Introduction.....	25
Methods.....	28
Results.....	36
Discussion	40
Chapter 3: Summary, Limitations, Practical Applications and Further Research	
Directions	44
Summary.....	45
Limitations.....	45
Practical Applications.....	46
Further Research Direction	46
Appendices.....	53
Appendix 1: Ethics Approval.....	53
Appendix 2: PAR-Q.....	54

List of Figures

Figure 1. Timeline of events	30
Figure 2. The Basketball Exercise Simulation Test (BEST), adapted from Scanlan et al. (2014).	33
Figure 3. Mean \pm SD a) perceived fatigue (1 = not physically tired at all to 5 = very physically tired) and; b) perceived muscle soreness (1 = no soreness to 10 = extremely sore) pre-exercise, post-exercise, and post-recovery in control (CON – dashed line) and compression (COMP - solid line) conditions.	37

List of Tables

Table 1. Mean \pm SD for pre-exercise, post-exercise, and post-recovery performance measures for control (CON) and compression (COMP) conditions.	37
Table 2. Post-recovery comparison of all performance measures and perceptual ratings compared to post-exercise. Data presented as raw difference in values (mean \pm 95% confidence intervals) with effect sizes for comparison between experimental (COMP) and control (CON) groups.....	38
Table 3. Mean \pm SD pressure measurements (mmHg) for the compression garments at post-exercise and post-recovery.....	38
Table 4. Sleep quality and duration for the control (CON) and compression (COMP) groups, with effect sizes between groups \pm 95% confidence intervals.....	39

Abbreviations

BEST: Basketball Exercise Simulation Test

CI: Confidence Interval

cm: Centimetres

COMP: Compression Garments

CON: Control

CV: Coefficient of Variation

h: Hours

ICC: Intraclass Correlation Coefficient

Kg: Kilograms

m: Metres

mmHg: Millimetres of Mercury

m/s: Metres per second

n: Number of Participants

PAR-Q: Physical Activity Readiness Questionnaire

RPE: Rate of Perceived Exertion

S: Seconds

SD: Standard Deviation

Thesis Overview

The format of this thesis includes a chapter presented in the style of an individual journal article format (Chapter 2), and consequently, some information may be repeated. This thesis comprises of three chapters; Chapter 1 contains a literature review on the effects of compression garments used for recovery and introduces the use of compression garments for the use in basketball. Chapter 2 is an original investigation studying the use of lower-body compression garments following exercise on next-day recovery in basketball athletes. Chapter 3 summarises the overall findings and suggests practical applications of this research and suggestions for further research.

Chapter 1: Literature Review

Compression garments overview

Compression garments have been reported to improve power and torque measurements, optimise blood flow, reduce inflammation, and decrease blood lactate and creatine kinase levels following muscle damage-inducing exercise (Davies, Thompson, & Cooper, 2009; Kraemer et al., 2010a; MacRae, Cotter, & Laing, 2011). The use of compression garments for recovery is reportedly due to the external force created on the skin by the garments, creating a pressure gradient that restricts the space available for swelling to occur following exercise (Duffield, Cannon, & King, 2010a; Marqués-Jiménez, Calleja-González, Arratibel, Delextrat, & Terrados, 2016; Pruscino, Halson, & Hargreaves, 2013; Xiong & Tao, 2018). Compression garments were originally used by medical professionals in post-operative patients to optimise blood flow and reduce blood clots (Marqués-Jiménez et al., 2016). Medical professionals found positive effects from the use of compression garments improving the recovery rate in patients and reducing the risk of further damage or harm in people with certain medical conditions such as lymphoedema and other chronic inflammatory disorders (Davies et al., 2009). Compression garments were also used during travel to reduce swelling and increase blood flow to prevent deep vein thrombosis (Davies et al., 2009). The use of compression garments became popular in many different sports due to the proposed improvement in maximal strength and power tasks, however, endurance exercises like submaximal running were seen to be unaffected by the use of compression (Sperlich & Holmberg, 2013; Xiong & Tao, 2018). Studies have been conducted on compression garments for recovery in many different sporting scenarios (e.g. rugby, cricket, cycling) (Duffield & Portus, 2007; Hamlin et al., 2012; Ménérier et al., 2013) and the different components of fitness

(strength, speed, endurance, power); overall these studies have shown mixed results (MacRae et al., 2011; Marqués-Jiménez et al., 2016).

Characteristics of compression garments

Compression therapy can be used in many different avenues of health including venous disease management (lower-limb compression garments to increase venous return back to the heart and reduce blood pooling in the lower-limb) (Lee et al., 2018), scar management (applying pressure to the hypertrophic scar to encourage healing in that area by increasing collagen lysis and repairing the wound) (Xiong & Tao, 2018), orthopaedic support (Xiong & Tao, 2018), and sportswear. For all these uses there are multiple different types of compression garments available for different parts of the body including stockings, bandages, sleeve, gloves, bodysuits and face masks (Brophy-Williams, Driller, Kitic, Fell, & Halson, 2017; Xiong & Tao, 2018), and there are over a hundred different types of compression garments for athletes around the world that are commercially available (Beliard et al., 2014).

Compression garments can be influenced by the garment dimensions, construction, and fabrics but also be influenced by the wearer, body dimensions, tissue type, posture, and movement (MacRae, Laing, & Partsch, 2016). Different methods of sewing are used to create compression garments. Garments aiming to apply higher levels of pressure are constructed as a one-piece with no seams, whereas garments regularly found in stores use the cut and sew method. The seamless designs have been noted as being more comfortable and cause less skin irritation (Xiong & Tao, 2018). There are also different types of knit patterns used for the material for example Warp patterns and Weft patterns giving greater elasticity or extension to garments in the

different directions; warp (vertically) and weft (horizontally) (Troynikov et al., 2010). Compression garments usually also include mesh components to allow for better air permeability and to fit better.

Compression garments have been reported to have different levels of comfort during wear due to the level of pressure. Pressure levels of 44.1-73.5mmHg have been found to cause discomfort (Xiong & Tao, 2018), whereas pressure levels of 14.7-29.4mmHg are in a comfortable zone (Xiong & Tao, 2018). Comfort levels may alter depending on the individual and the part of the body in which compression is being applied (Xiong & Tao, 2018). Pressure levels around the shoulder and groin area cannot be too tight, as this can lead to suppressed blood flow on the skin to the peripheries and delay blood pressure recovery following activity. Researchers found in swimsuits that compression on the trunk below 7.5mmHg was beneficial however pressures exceeding 8.6mmHg for the chest, 2.7mmHg for the Waist and 4.3mmHg for the abdomen would influence the comfort of the wearer (Xiong & Tao, 2018).

Previous research has claimed that compression garments need to exert pressure levels of approximately 17mmHg at the leg and 15mmHg at the thigh to improve venous blood return (Watanuki & Murata, 1994). Hill et al. (2017) studied the pressures exerted by compression garments for recovery, showing that a pressure level of $14.8\text{mmHg} \pm 2.2$ and $24.3\text{mmHg} \pm 3.7$ at the thigh and calf respectively, was more effective at improving muscle function than garments with pressure levels of $8.1\text{mmHg} \pm 1.3$ and 14.8 ± 2.1 m at the thigh and calf respectively. Although multiple studies have recommended certain pressure levels are more beneficial, the majority of the studies currently available do not record the pressure of the garments being tested.

It has been reported that only one in every three studies record the applied pressure measurement (MacRae et al., 2016).

Physiological effects of compression garments

Compression garments have been reported to; reduce muscle oscillation, reduce inflammation and muscle damage markers (creatine kinase) in the blood, reduce limb size, reduce space available for swelling, increase blood lactate clearance and increase blood flow (Duffield et al., 2010a; Marqués-Jiménez et al., 2016; Pruscino et al., 2013; Xiong & Tao, 2018).

Sperlich and Holmberg (2013) reviewed 31 studies, which included physiological, psychological and biomechanical effects of compression garments used during and after exercise. This review found that compression garments needed to be worn for at least 12h to 24h following exercise to have any influence on the rate of recovery. Results after wearing compression garments for 12h-24h following exercise showed beneficial results for reduced muscle swelling and reduced muscle soreness when compared to garments worn for less than 12h (Sperlich & Holmberg, 2013). The review concluded that wearing compression garments for 12-48h after exercise inducing muscle damage will have *moderate* effects on reducing muscle swelling, perceived muscle soreness and blood lactate levels (Sperlich & Holmberg, 2013).

A review spanning 2 years found inconclusive results for the effects on the physiological functions (blood lactate, lactate dehydrogenase, creatine kinase, VO₂, c-reactive proteins, and plasma levels) as a result of using compression garments for recovery (MacRae et al., 2011). MacRae et al., (2011) reported studies showing

beneficial effects of lower lactate levels after using compression garments (Berry & McMurray, 1987; Chatard et al., 2004), but also found studies with no effects on creatine kinase, lactate dehydrogenase, plasma myoglobin and c-reactive protein levels (Davies et al., 2009; French et al., 2008; Gill, Beaven, & Cook, 2006) from using compression garments for recovery when compared to a control group. MacRae et al. (2011) stated it is important to note that some beneficial results (e.g. lower lactate levels) may not influence long-term adaptive responses, as there might be an alternative reason behind the results (e.g. lactate being retained in the muscle). MacRae et al., (2011) concluded that beneficial results for physiological markers of recovery are isolated and inconclusive and therefore require corroboration.

Duffield et al. (2010a) conducted a randomised counter-balanced study on 11 team-sport athletes who regularly trained 3-4 times and played one competitive game per week. Participants either wore compression garments during and after exercise (experimental) or did not wear compression garments throughout exercise or for recovery (control). Blood samples were taken before exercise, immediately post-exercise, 2h and 24h post-exercise. Blood samples were tested for changes in muscle damage and inflammation markers, these markers were blood lactate, pH, creatine kinase, C-reactive protein, and aspartate transaminase. Muscle damage and inflammation markers in the blood were increased at 2h post and 24h post but showed no significant differences and *small* effect sizes between the conditions for blood lactate, pH, creatine kinase and C-reactive protein. A *moderate* effect size was shown for a reduced aspartate transaminase value at 24h post in the compression garment group compared with the condition but no significant differences were found between the conditions. Despite *small* to *moderate* effect sizes, Duffield et al., (2010)

concluded that the compression garments did not have any beneficial effects on recovery following 24h of wear when compared with the control group.

Davies et al. (2009) conducted a crossover design study on 7 female netball players and 4 male basketball players to find out if compression garments shorten recovery time. An exercise protocol of 5 sets of 20 drop-jumps off a 60cm platform, with a maximal jump at the bottom and 2 minutes rest between sets was performed. Groups then either wore compression garments for 48h or no compression garments for 48h. Participants were tested on creatine kinase level and lactate dehydrogenase level. Davies et al. (2009) concluded their study did not show any beneficial physiological effects from wearing compression garments over 48h.

Eight field hockey players performed the Loughborough Intermittent Shuttle Test (LIST) as a match simulation then wore graduated lower limb compression garments or loose-fitting pants for 24h (Pruscino et al., 2013). Blood testing was performed pre-exercise; 1h, 24h, and 48h post-exercise and investigated IL-6, IL-1 β , TNF- α , C-reactive protein and creatine kinase. Blood lactate was also monitored throughout the exercise and for 30 minutes after (Pruscino et al., 2013). No significant difference was found between conditions for IL-6, IL-1 β or TNF- α ($p > 0.05$). Creatine kinase and c-reactive protein both peaked 24h post-exercise for both conditions, however, there were no significant differences between conditions ($p > 0.05$) (Pruscino et al., 2013). Blood lactate levels also showed no difference between conditions from 0-30minutes post-exercise (Pruscino et al., 2013). Overall no differences in clearance rate or reduction in biochemical markers were shown between compression garments and the control group.

A study testing the efficacy of compression garments included 17 female participants who were allocated to either the full length lower limb compression group, (n=8) or the passive recovery group (n=9). Participants completed 10 x 10 plyometric drop jumps from a 0.6m box before completing 12h in the allocated recovery group (Jakeman, Byrne, & Eston, 2010). Creatine kinase levels were tested prior to muscle damage-inducing exercise and then 1h, 24h, 48h, 72h, and 96h post-exercise. Results showed that creatine kinase levels changed significantly over the recovery period but did not show any significant differences when compared between the two groups ($p > 0.05$) (Jakeman et al., 2010).

Gill et al. (2006) conducted a study on 23 elite male rugby players examining the effectiveness of recovery interventions on the rate and magnitude of muscle damage measured by creatine kinase. Measures were taken immediately after exercise, 36h, and 84h after exercise. Compression garments were worn overnight for approximately 12h following the athlete's normal post-match routine. No significant differences were found between the effects of compression garments on creatine kinase levels compared to contrast water therapy and active recovery at any time point following activity (Gill et al., 2006). Compression garments and other recovery protocols showed beneficial results at 36h and 84h after a rugby match compared to the passive recovery group. Although beneficial results were found compared to passive recovery, Gill et al., (2006) concluded that optimal duration for wearing compression garments requires further investigation for the effects on creatine kinase levels.

Overall physiological responses to compression garments used for recovery in team sports are contradictory with some studies revealing beneficial results in lactate clearance, creatine kinase levels, arterial flow, and venous return, however other studies did not show any differences between groups for the various physiological measures. Contradicting findings may be the result of a range of methods being used throughout the studies (e.g. different time frames for recovery and testing, exercise to induce muscle damage, the gender of participants) and pressure levels either not being recorded or being insufficient to induce any physiological effect.

Performance effects of compression garments

Compression garments have been reported to speed up recovery to improve post recovery performance and decrease the influence of fatigue on subsequent performances.

MacRae's review (2011) on the use of compression garments on subsequent performance found both beneficial and non-beneficial results. No significant difference was found between control and experimental groups for sprint, agility, squat or countermovement jump performances in multiple studies (Davies et al., 2009; Duffield, Cannon, & King, 2010b; French et al., 2008; Kraemer et al., 2010a), however, performances of various power and torque movements showed benefits from the use of compression garments compared to a control group (Jakeman et al., 2010; Kraemer et al., 2001). MacRae et al., (2011) suggests testing should be completed to reflect actual recovery time in search of results, as significant results can be found at certain times during the recovery period but may not be present at other times. An example given for this is a study by Perrey et al. (2008), where benefits

were found at 24h but not at 2h, 48h, or 72h for peak evoked twitch of plantar flexors, thus showing that depending on when researchers test the participants may affect if any significant results were found or not (MacRae et al., 2011).

Brown et al. (2017) conducted a meta-analysis on compression garment use for recovery including 23 studies. The results from these studies were classified in groups; these groups were split by; time compression garments were worn (0-2h, 2-8h, 21h, and >24h), by pressure level (<15mmHg and >15mmHg) and also by training status of participants. Results showed that pressure levels and training status did not have any influence on the *very likely* benefits from compression garment use (Brown et al., 2017). Compression garment use for recovery is stated to have the greatest benefits following resistance exercise when worn for >24h. Strength levels following compression garment use for recovery showed the largest benefits following 2-8h and >24h wear (Brown et al., 2017).

Sperlich and Holmberg (2013) conducted a review on 31 studies and found compression garments had *small* positive effects on 10-60m sprints, vertical jump height, time trial performance, and time to exhaustion tests. This review came to the conclusion that compression garments worn for 12-48 hours had *moderate* effects on maximal strength and power performance (Sperlich & Holmberg, 2013).

Duffield et al. (2010a) as mentioned above, conducted a randomised counter-balanced study on 11 trained team-sport athletes who regularly trained 3-4 times and played one competitive game per week. Participants wore compression garments during and after exercise for 24 hours or no compression garments at all. Physical test of 20m

sprints and double leg bounds from a stationary position were conducted pre-exercise, immediately post, 2h post, and 24h post-exercise. Duffield et al. (2010a) did not find any significant difference between groups for 20m sprints or double leg bound distance at any time points, concluding compression did not have any effects on consecutive day performance.

A match-paired design was used to evaluate the use of contrast bathing and compression garments compared to a control group. This study included 26 males with ≥ 4 years experience at a recreational-regional level for their respective sport, and ≥ 1 year experience of resistance training (French et al., 2008). The study was conducted over three weeks. Participants completed familiarisation sessions one week before baseline data collection commenced; testing included range of movement for right leg (hip flexion, extension, and abduction; knee flexion and extension; ankle dorsiflexion), a countermovement jump and repeated countermovement jumps, 10 and 30m sprints, multidirectional agility 'M' test, and 5 repetition maximum parallel back squats. After two weeks participants completed a resistance exercise challenge including 6 x 10 parallel back squats at 100% body weight with the 11th rep at a predicted 1 repetition maximum effort. Within ten minutes of completing the resistance exercise challenge, participants began their recovery treatment intervention. The compression garment group wore commercially available full-length lower limb tights following the manufacturer's sizing chart for 12h overnight, (average pressure rating of 12mmHg at the calf and 10mmHg at the thigh) (French et al., 2008). Participants completed performance-testing 48h after recovery intervention commenced. Results showed flexibility was significantly lower ($p \leq 0.05$) for ankle dorsiflexion in the control group compared to the compression group at 48h post-

exercise. Results for the remaining performance test, (knee flexion and extension, countermovement jumps, hip range of movement, 'M' test, 10m and 30m sprint times) showed no significant differences between groups (French et al., 2008). Compression garments used for recovery had no significant effects on performance measures following a resistance exercise challenge.

A mixed measures design study conducted on 19 male club level rugby players tested the efficacy of compression garments on recovery of performance measures (countermovement jump and maximal voluntary isometric contraction) following a muscle-damaging rugby specific exercise protocol, compared to a 'SHAM' recovery drink group (Upton, Brown, & Hill, 2017). The muscle-damaging rugby specific exercise protocol consisted of 20x maximal 20m sprints with a 10m deceleration or finishing with a tackle bag slam (squat, pick the tackle bag up and slam it to the ground) after every other sprint to replicate rugby movements on the minute every minute. Immediately following the exercise protocol participants showered and then were allocated a recovery group, either compression where they had to wear full-length lower-limb compression (average pressure calf: 14 ± 4.1 mmHg, thigh: 8.5 ± 2.3 mmHg) for 48h (only to be taken off to be washed), or the SHAM group who had to consume a recovery drink. Performance measures were recorded at baseline then immediately after exercise, and then 24h and 48h after the exercise protocol. Countermovement jump performance did not show any significant difference in results between groups at any time point ($p \geq 0.05$). Maximal voluntary isometric contraction showed an increase in strength for the compression group at 48h post-exercise, however, the difference was not significant between the two conditions ($p \geq 0.05$) (Upton et al., 2017). Therefore compression garments did not have any

beneficial effects on performance following rugby specific exercise for club-level athletes. Conclusions however, stated that there was insufficient pressure being applied by the compression garments causing the lack of effect on the participants.

A crossover design was used to evaluate the effects of compression garments worn for 24h following resistance exercise on 11 men and 9 women. The resistance exercise session to induce muscle fatigue included 3 sets of 8-10 repetition maximum loads, with 2-2.5min rests between sets for 8 different exercises (back squats, bench press, stationary lunge, bent-over row, Romanian deadlift, bicep curls, sit-ups, and high pull from a hang). The recovery protocol included a shower and then wearing compression garments or non-compressive clothing overnight for 24h, participants then removed compression garments for the post-recovery performance tests (Kraemer et al., 2010a). Participants completed performance tests immediately after the exercise session and then 24h after the exercise sessions. Performance tests included a movement reaction time test, 10x countermovement vertical jumps to test for peak power, average power and performance decrement, a bench press throw and a squat jump. The bench press throw, and squat jump were performed in a modified smith machine to test peak power, force, and velocity. All tests and protocols had been performed in a familiarisation session so no learning effects were present (Kraemer et al., 2010a). A significant difference was found between conditions for the bench press throw ($p < 0.05$), however, no significant differences were found between the condition groups for any other performance measure (squat jump, reaction time, countermovement vertical jump peak power, average power or performance decrements). Kraemer et al. (2010a) discussed that the participants were well trained in resistance exercises and have had previous exposure to the heavy loading, therefore

they were familiar to recovery for this type of exercise, which may have influenced the results.

The study by Pruscino et al. (2013) on eight field hockey players as mentioned previously studied the effects of compression garments compared to loose clothing following 24h of wear. This study investigated performance measures of 5 countermovement jumps and a squat jump, tested pre-exercise, 1h post, 24h post, and 48h post-exercise. Results showed no significant differences were found between conditions for squat jump but showed a significant difference between the conditions at 48h post-exercise ($p < 0.05$) for power productions during 5 countermovement jumps (Pruscino et al., 2013).

Participants in the Jakeman et al. (2010) study, performed 10 x 10 plyometric drop jumps to induce muscle damage before completing performance tests. Jump heights, flight times, and knee extensor strength tests were completed prior to exercise, and 1h, 24h, 48h, 72h, and 96h after exercise tested for differences between a compression garment group and a passive recovery group (no intervention). Muscle strength was tested using an isokinetic dynamometer on knee extension. Jump height and flight times were tested from squat jumps and vertical jumps using the Optojump infrared jump system (Jakeman et al., 2010). Significant differences in favour of the compression group were present between groups at 24h, 48h, 72h, and 96h post muscle-damaging exercise for isokinetic muscle strength (knee extension) ($p < 0.01$) and squat jump height ($p < 0.01$). A significant difference was also present 48h post-exercise for countermovement jump height, in favour of the compression group (Jakeman et al., 2010) concluded that compression garments used immediately

following muscle-damaging exercise had beneficial effects on recovery for jump performance and muscular strength performance.

Compression garments showed contradicting results throughout the studies when testing performance measures for strength, power, and endurance with some studies showing beneficial effects while others showed no difference between condition groups. Studies that resulted in no difference, suggested reasons as to why there may not have been any significant results and suggested further research in the areas is required.

Psychological effects of compression garments

Ratings of muscle soreness, vitality, quality of sleep and fatigue levels were reported in a review by MacRae et al. (2011). Multiple studies included in this review reported beneficial results from the use of compression garments (Ali, Caine, & Snow, 2007; Duffield & Portus, 2007), however, others reported no differences between compression garment groups and control groups (Davies et al., 2009; French et al., 2008). This review on compression garments used for post-exercise recovery concluded that compression garments tend to be better, or no worse than without compression garments and did not show any negative effects caused by compression (MacRae et al., 2011).

Jakeman's study (2010) induced muscle damage using plyometric drop jumps to test for perceived muscle soreness on a scale of 0 (no pain) to 10 (worst pain ever) while assuming an unweighted squat position. The squat test was performed prior to exercise, 1h, 24h, 48h, 72h, and 96h following exercise to test for differences between

compression garment group and passive recovery group (no intervention) (Jakeman et al., 2010). Results showed a significant group x time interaction ($p \leq 0.05$) and group effect ($p < 0.01$), these results were in favour of the compression garment group, which experienced a significantly lower muscle soreness rating at 1h, 24h, 48h, and 72h post-exercise (Jakeman et al., 2010).

A study comparing contrast water therapy and full length lower limb compression stockings to passive recovery, on subsequent cycling performance was completed on 12 competitive male cyclists in a randomised crossover design (Ménérier et al., 2013). Participants performed a tiring exercise on the cycling ergometer, then a 5min performance test, they then completed the recovery protocols for 15 minutes followed again by the 5min performance test. Participants were asked to rank pain on a scale 1-10 to assess muscular soreness, 0= normal and 10 = extremely sore, pain was reported at baseline, before, and after recovery took place (Ménérier et al., 2013). Contrast water therapy and compression showed significantly lower pain levels compared to passive recovery with no significant difference between contrast water therapy and compression showing both techniques for recovery were beneficial for reducing perceived muscular pain (Ménérier et al., 2013).

Brophy-Williams et al. (2017) conducted a counterbalanced crossover design study on the effects of compression socks for recovery. Participants in this study were twelve well-trained male runners, who ran at least 4 times per week for the last 3 years and had previous experience wearing compression socks. Participants were asked for a rating along a 10cm visual scale, 0cm being strongly disagreed and 10cm being strongly agreed for the following statement, “compression socks improved recovery

between repeated running bouts". The experimental design consisted of a familiarising session and two experimental sessions in a climate-controlled laboratory. Each exercise session included a warm-up consisting of three 4-minute blocks of submaximal running at 60%, 70%, and 80% of self-reported 5km pace, with 1-minute rest between each block after the warm-up participants completed a 5km time trial on a treadmill at maximal pace followed by a 60min recovery period. The recovery period consisted of participants receiving a carbohydrate drink and a muesli bar and either wearing compression socks or no compression socks while remaining in a seated position at rest for the entire 60minutes (Brophy-Williams et al., 2017). After the 60min recovery period finished, participants performed a second exercise bout with the warm-up and 5km time trial. During both time trials, participants were blinded to their speed and duration and had to indicate to the researcher if they wanted to speed up or slow down, each 500m completed participants were informed of their progress until the final 500m where they were updated every 100m. Results showed that participants in the control group (no compression) had significantly slower second time trial compared to no difference shown in the compression garment group. The compression garment group showed a *moderate* ($d = 0.79$) and significant effect (< 0.01) on reducing muscle soreness in the recovery period compared to the control group (Brophy-Williams et al., 2017). The study also investigated the effects of perceptions on compression garments, comparing those that believed compression would have an effect on recovery between running bouts against those that did not believe there would be an effect. By grouping the participants in believers vs. non-believers results showed a significantly slower time trial two compared to time trial one in the control condition for believers ($d = 0.23$, $p = 0.02$). No significant decline was present in performance measures between trials in the compression condition ($d =$

0.05, $p = 0.32$). There was no difference present between trials or conditions for nonbelievers. A *small* effect size (control: $d = 0.14$, $p = 0.02$; compression: $d = 0.19$, $p = 0.04$) was present in the performance decrements between groups, which showed a beneficial effect on performance for believers compared to non-believers ($d = 0.25$, $p = 0.07$) (Brophy-Williams et al., 2017). Brophy-Williams et al., (2017) concluded that compression garments had a beneficial effect on perceived muscle soreness during recovery and had an effect on aiding recovery, especially when participants believed compression would help improve recovery between exercise bouts, indicating a strong potential for a placebo effect to be present.

Kraemer et al. (2010a) studied the perceived responses of wearing compression garments for 24h following exercise for recovery on 11 men and 9 women. Multiple scales were used to assess different psychological components including, rating of perceived soreness for different muscle when palpated over, was recorded on a Likert scale 0 (no soreness) to 10 (maximum possible soreness). A 5-point Likert scale was used to show the soreness of different body parts when talked about. A 10cm line labelled from the left (no soreness) to right (extreme soreness) was used to visual rate the overall perceived soreness. To measure fatigue, a 10-point scale was used 0 (minimum) and 10 (maximum possible). Measures of vitality and sleep were recorded on a 6-point scaling. Results showed significantly lower ratings of muscle soreness in favour of the compression group for the 10-point scale when palpated over and the 10-point overall visual scale. Significant differences were found for soreness ratings between left and right torso however no other perceived ratings were found to be significant (Kraemer et al., 2010a). Kraemer et al., (2010) concluded that for both groups there was a rapid recovery rate for muscle soreness, vitality and fatigue levels

over the 24h recovery period, indicating that the participants were either use to the type of exercise or it did not originally induce a great amount of muscle soreness.

The Davies et al. (2009) study on 7 female netball players and 4 male basketball players used an exercise protocol of 5 sets of 20 drop-jumps off a 60cm platform, with a maximal jump at the bottom and 2minutes rest between sets was performed. Then the groups either wore compression for 48h or no compression garments for 48h. The rating of perceived muscle soreness was tested at baseline and then at 24h and 48h after exercise protocol was complete. Perceived muscle soreness rating was taken on an adapted Mattacola Graphic Ratings Scale (Mattacola, Perrin, Gansneder, Allen, & Mickey, 1997). No significant differences were found between the condition groups for perceived muscle soreness at any time points throughout the study (Davies et al., 2009). Subjects felt that wearing the compression garments negatively affected their sleeping pattern as they were uncomfortable to wear and increased their body temperature which may have influenced the results (Davies et al., 2009).

Psychological effects have tended to favour the compression garments for recovery, showing either beneficial results or no significant difference between control and compression groups. This shows that compression garments improved recovery and otherwise had little to no effect on the wearer and did not cause significant negative effects.

Compression garments in basketball

Basketball is one of the most popular organised sports for men and women of all ages around the world (Atkins, 2012). Basketball is classified alongside sports such as volleyball, football, and tennis where both aerobic and anaerobic energy sources are used (Crisafulli et al., 2002). The aim of the game is to score more points by getting the ball through the basket or 'hoop' while trying to stop the other team from scoring, to achieve this players do many repeated high-intensity bouts with rapid accelerating and decelerating (Montgomery, Pyne, Cox, et al., 2008) with a lot of stopping, changing direction, jumping, catching, passing and rebounding (Montgomery, Pyne, Hopkins, et al., 2008). Basketball is a game played by two teams with five players taking the court at a time per team over a 40minute period (Crisafulli et al., 2002). Sallet, Perrier, Ferret, Vitelli, and Baverel (2005) categorised basketball players in three categories based on height and weight, these are known as positions; guards, forwards and centres. Centres are the tallest and heaviest (203.9 ± 5.3 cm and 103.9 ± 12.4 kg), compared to forwards (195.8 ± 4.8 cm and 89.4 ± 7.1 kg) and guards (185.7 ± 6.9 cm and 82 ± 8.8 kg) (Sallet et al., 2005). During the basketball season, athletes will play 1-2 competitive games per week and have 1-3 practice sessions, leading up to a pinnacle event such as a national or international tournament at the end of the season. Playing and practicing up to five times a week means the athletes need to recover within 24h for consecutive day performances. Similarly, at a national tournament, athletes will play 2 games a day for 3-4 days in a row giving them less than 24h for recovery.

Montgomery, Pyne, Hopkins, et al. (2008), conducted a study on 29 male basketball players, these athletes typically performed 3-4 team practices and 1-2 individual

shooting and skill sessions per week with a total of 8-10h. Basketball athletes participated in a 3-day tournament with one 48-minute game per day, before the tournament participants were allocated a recovery group; carbohydrate and stretching, cold-water immersion, or compression garments. Following the completion of the game, the compression garment group rested for 15 minutes then wore full-length lower-limb compression for ~18h overnight. Basketball players were tested on line-drill ability, 20m-acceleration, agility, vertical jump height, sit and reach test, muscle soreness, general fatigue, and thigh and calf girth. Compression garments showed positive effects on maintaining the line-drill ability and a *large* benefit of minimising further decrements in vertical jump performance. Thigh and calf girth measurements showed *trivial* changes between games and post-tournament, the girth measurements increased immediately following exercise and returned to baseline the next morning for all recovery groups. The compression garment group showed substantial benefits in minimising muscle soreness compared to the control group throughout the tournament, the compression group also showed a *very large* decrease in 20m-acceleration time compared to the other recovery groups. There were no substantial positive effects on agility, and the sit and reach test showed a decreased range of movement with no beneficial effects from the compression garments (Montgomery, Pyne, Hopkins, et al., 2008).

Other than the mentioned studies, there is currently limited research available on the effects of compression garments for recovery in the basketball setting. This shows a gap in the literature and the opportunity to complete further research into an under-represented area.

Conclusion

Inconclusive results have arisen for the effects of compression garments on recovery from the current literature being reviewed; there are both positive and negative effects for all of the components of recovery (physiological, performance and psychological). These inconclusive results have been explained by, the range of different methods used to test the compression garments, the pressure levels applied to the athletes wearing them, and the training status of those athletes all having influential factors on the results in each study. Overall further research has been suggested and the inclusion of the applied pressure needs to be recorded to add to the current literature on the optimal level of pressure needed for beneficial results. There is currently limited information on the sport-specific benefits for team sports that involve multiple components of fitness (power, speed, agility, and endurance). The lack of information surrounding the use of compression garments for recovery in basketball has shown a need for more research in this area.

**Chapter 2: Lower-body compression garments worn
following exercise improves perceived recovery but not
subsequent performance in basketball athletes**

(Under review in the Journal of Sports Sciences)

Abstract

This study examined the effects of lower-body compression garments worn following exercise on perceived recovery and subsequent performance in basketball athletes. In a parallel-group design, 30 recreational, male basketball athletes were allocated to either a control (CON, n = 15, loose-fitting clothing) or experimental group (COMP, n = 15, compression garments) for 15h following fatigue-inducing, basketball-specific exercise. The evening exercise bout (1600-1800h) included performance of the Basketball Exercise Simulation Test, lunge jumps, and an isometric wall sit exercise. Perceptual measures of fatigue and muscle soreness as well as physical performance tests were performed pre-exercise, post-exercise, and post-recovery (15h following exercise). Subjective and objective measures of sleep were recorded following the exercise trial. There were non-significant ($p > 0.05$), *unclear-trivial* differences between groups for all performance measures. Perceived post-recovery fatigue ($d = -1.27$, *large*) and muscle soreness ($d = -1.61$, *large*) were significantly lower in COMP compared to CON ($p < 0.05$). COMP exhibited better perceived sleep quality ($d = 0.42$, *small*, $p = 0.18$) than CON, with an *unclear* difference in sleep duration between groups ($p > 0.05$). Wearing lower-body compression garments overnight improved perceived fatigue and muscle soreness, but had negligible effects on subsequent physical performance in basketball athletes.

Keywords: *fatigue; sprint; vertical jump; agility; sleep*

Introduction

The use of compression garments to enhance athletic recovery has become one of the most popular recovery strategies among elite athletes (Driller & Brophy-Williams, 2016; Tavares, Healey, Smith, & Driller, 2017). Recreational athletes are also opting to use compression garments to aid recovery following exercise. Research suggests compression garments may optimise blood flow; decreasing blood lactate and creatine kinase concentrations, and subsequently reducing muscle soreness (Duffield et al., 2010a; Marqués-Jiménez et al., 2016; Pruscino et al., 2013) and the inflammatory response by restricting the space available for swelling (Marqués-Jiménez et al., 2016; Pruscino et al., 2013). These aspects may combine to increase the overall efficiency of recovery to optimise and restore muscle function more promptly following fatiguing exercise (Duffield et al., 2010a; Pruscino et al., 2013).

Inflammatory markers of muscle damage and delayed onset of muscle soreness typically take from 72 hours up to 5 days before returning to baseline without the use of any recovery interventions to expedite this process (French et al., 2008). Application of compression garments has been supported to provide some relief following muscle-damaging exercise (Gill et al., 2006); however, a meta-analysis revealed compression garments elicited greater benefits following resistance or plyometric exercise than after endurance exercise (Brown et al., 2017). Consequently, compression garments may provide benefits to team sports requiring frequent bouts of explosive activity.

Basketball is a team sport predicated on the repeated expression of power-driven movements (Wen, Dalbo, Burgos, Pyne, & Scanlan, 2018), with basketball athletes performing various high-intensity, power-related movements encompassing frequent multi-directional acceleration, deceleration, and jumping manoeuvres (Stojanović et al., 2018). Consequently, muscle damage is inevitable for most basketball athletes following game-play (Brown et al., 2017; Montgomery, Pyne, Hopkins, et al., 2008). Previous research documented substantial increases in muscle damage (creatinine kinase and myoglobin) and inflammation (C-reactive protein, leukocytes, and cytokines) markers following elite (Chatzinikolaou et al., 2014) and sub-elite games (Montgomery, Pyne, Cox, et al., 2008). These responses associated with basketball game-play may contribute to increased perceptions of muscle soreness in athletes, which are further compounded when playing multiple games on successive days during tournament-style competitions (Montgomery, Pyne, Hopkins, et al., 2008). In this way, the only study to examine the recovery effects of compression garments following basketball activity examined tournament game-play in sub-elite athletes (Montgomery, Pyne, Hopkins, et al., 2008). This study compared three recovery groups including a control (n=9), cold-water immersion applied post-game (n=10), and lower-body compression garments worn for ~18 h post-game (n=10). While cold-water immersion was shown to be the superior recovery approach, compression garments offered benefits (presented as % difference between conditions with 90% confident limits) in repeated-sprint time ($-1.8\% \pm 1.9\%$), perceived muscle soreness ($-0.9\% \pm 1.5\%$) and fatigue ($-1.1\% \pm 2.0\%$) throughout the 3-day tournament compared to the control group (Montgomery, Pyne, Hopkins, et al., 2008).

While the initial study by Montgomery et al. (2008) offers useful insight, a wider evidence-base is needed for definitive recommendations regarding the use of compression garments as an efficacious recovery option for basketball athletes to be made. In particular, given the strong popularity of basketball among the general population in many countries, including the United States of America and Australia (Scanlan, Dascombe, Kidcaff, Peucker, & Dalbo, 2015), research examining compression garments in recreational athletes is needed. Such data would inform potential recovery strategies that may allow more frequent participation in basketball activity and thus bring greater associated health benefits such as improvements in aerobic fitness, lean body mass, bone mineral density, and arterial blood pressure (Randers et al., 2018), for the general population. Therefore, the aim of the current study was to evaluate the effect of wearing lower-body compression garments following basketball-specific, fatigue-inducing exercise (overnight) on perceptual ratings of recovery and physical performance in recreational, male basketball athletes.

Methods

Participants

Thirty trained male basketball athletes (mean age: 22.5 ± 4.1 years, height: 179.3 ± 4.0 cm, body mass: 71.7 ± 6.3 kg, playing experience: 6.2 ± 3.8 years) volunteered to take part in the study. Inclusion criteria required the participants to be free from lower-limb injury for the previous 6 months prior to participation, aged 18-35 years, be playing competitive basketball at the club level, and pass a Physical Activity Readiness Questionnaire (PAR-Q) and medical clearance. The study took place during the pre-season phase of the basketball competition. Written informed consent was obtained from each participant, and ethical approval was approved by an institutional Human Research Ethics Committee.

Experimental Design

Using a parallel-groups study design, participants were allocated to either a compression group (COMP, $n = 15$) wearing a lower-body compression garment for ~15 hours (overnight) following exercise or a control group (CON, $n = 15$) wearing loose-fitting clothing for ~15 hours (overnight) following exercise (Figure 1). On arrival at the laboratory at 16:00, participants performed a standardised warm-up and a familiarisation of the Basketball Exercise Simulation Test (BEST) protocol (Scanlan et al., 2014). Participants then completed baseline (pre-test) measurement of perceptual ratings and a performance testing battery, followed by a full trial of the BEST, jumping lunges, and an isometric wall sit. Following the basketball-specific, fatigue-inducing exercise, the second testing session (post-test) was conducted with perceptual ratings taken again and the performance testing repeated. Participants were then given loose-fitting clothing or full-length, lower-body compression garments (Li-

Ning, PowerShell AULM043-I, Beijing, China) and a wrist-worn sleep monitor (Xiaomi, MI band 2, Beijing, China) to wear following a 5-min warm shower. The garment pressures were recorded immediately after they were put on. Each participant then received a standardised dinner at 18:30 and was placed in an environmentally controlled (temperature and light) sleep laboratory (temperature: $21.8 \pm 0.9^{\circ}\text{C}$; humidity: $49 \pm 4\%$) until the next morning. Participants were only allowed to leave their rooms to go to the bathroom. Electronic devices (e.g. mobile phones) were not permitted after 21:00, and at this time all lights were turned off. At 07:30 the following morning, lights were turned on with garment pressures and perceptual ratings measured between 07:30-07:40. Participants gave ratings of sleep quality, which were recorded alongside objective sleep measures. Participants then completed the standardised warm-up before completing the performance testing battery again at 08:00.

Testing was completed at the same time each day for both groups to account for diurnal variations in performance. Participants were not permitted to use any additional recovery strategies (e.g. active recovery, stretching, cold-water immersion) or take anti-inflammatory/pain medications or other supplements to aid their recovery.

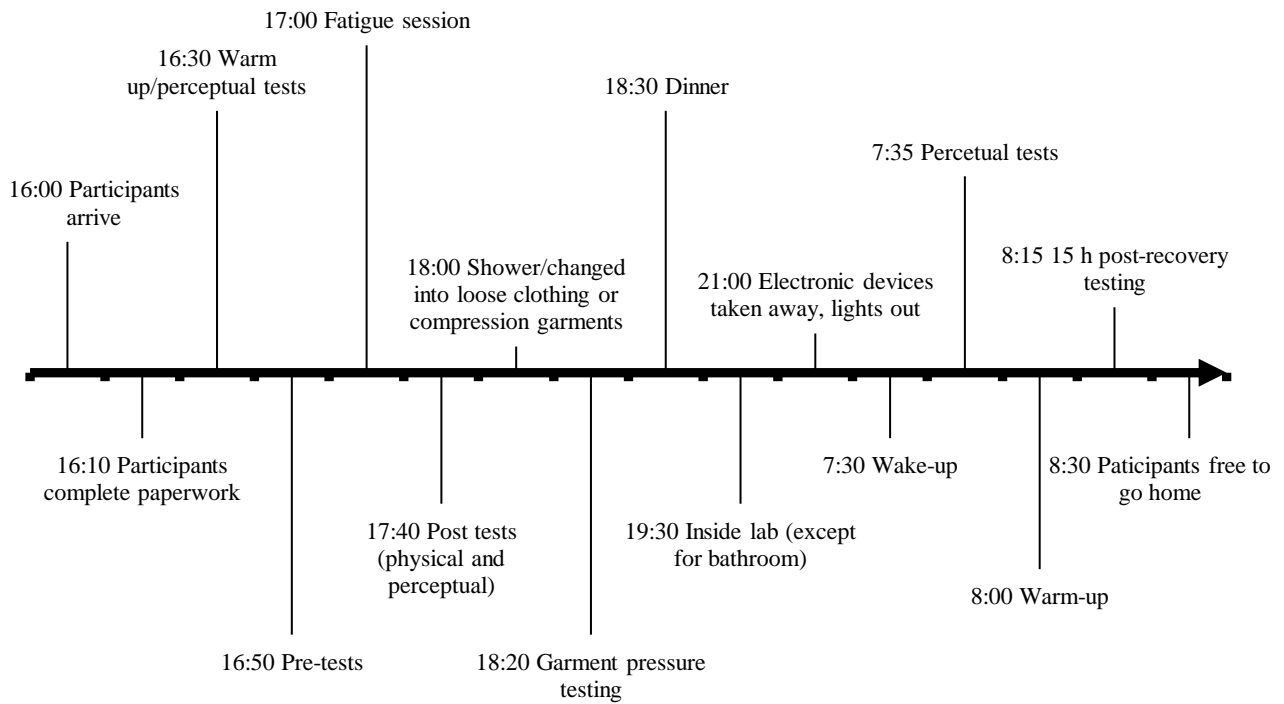


Figure 1. Timeline of events

Procedures

The standardised warm-up consisted of moderate-intensity jogging, a range of dynamic stretches, and then running efforts of increasing intensity across the length of the basketball court. Furthermore, three submaximal- and one maximal-effort circuit of the BEST were completed as part of the warm-up. Immediately following the warm-up, perceptual ratings were recorded and a standardised testing battery of basketball-relevant performance tests was administered.

Perceptual measures

The 10-point Mattacola scale (Mattacola et al., 1997) was used to measure muscle soreness following the warm-up, after the fatigue-inducing exercise session, and the

following morning after waking (~15 h post-exercise). The scale included ratings from 1 = no soreness to 10 = extremely sore. Similarly, fatigue was rated using a 5-point Likert scale (Pruscino et al., 2013) at the same time points (ratings ranged from 1 = not physically tired at all to 5 = very physically tired).

Countermovement jump

A countermovement vertical jump was used to assess lower-body power. Outcome measures gathered included jump height using a Vertec apparatus (Sports Imports, Columbus, OH, USA) as well as vertical jump impulse (N·s) using a force plate sampling at 1000 Hz (AMTI, Watertown, NY, USA). Five countermovement jumps were performed involving participants initially standing with feet shoulder-width apart on the force plate. Participants were asked to jump as high as possible following a self-selected depth countermovement. Participants jumped from both feet and were permitted to use a swinging arm movement. Prior to the first jump trial, the hand reach height (baseline) was measured when the participant displaced the vanes of the Vertec apparatus with their fingertips. At the peak of the jump, participants had to displace the Vertec vanes lightly with their fingertips to indicate jump height. Jump height was then calculated by subtracting the participant's baseline reach height from the maximum jump height, as validated previously. Five jumps were performed with 2 s between each jump. The highest jump of the five trials was used for analysis.

Repeated-sprint test

A repeated-sprint test was used to evaluate maximum speed and anaerobic capacity. Participants began the repeated-sprint test positioned 10 cm behind the first timing gate (Smart Speed Timing Gates, Coopers Plains, Australia). The repeated-sprint test

consisted of 6 x 20-m sprints, each completed every 20 s and interspersed with passive standing rest. Each sprint was recorded to the nearest 0.001 s and the fastest sprint; as well as the total of all sprints were taken as outcome measures. Sprint decrement (%) was also calculated as $\text{total time/ideal time} \times 100$ where total time was the sum of all sprint times and ideal time was the best sprint time multiplied by six (Spencer, Fitzsimons, Dawson, Bishop, & Goodman, 2006).

5-0-5 Agility test

To assess change-of-direction speed, participants completed two trials of the 5-0-5 Agility test. Participants commenced each trial positioned in a starting position at the 0 m mark and initiated a straight-line sprint for 15 m where they performed a 180° turn on a marked point and sprinted in the opposite direction for 5 m back towards the starting line. The timing lights (Smart Speed Timing Gates, Coopers Plains, Australia) were placed at the 10 m mark so they could capture the start and stop times for the 5-0-5 test. Participants completed a trial with each foot as the plant foot when initiating the turn and 30 s of passive standing rest was applied between trials. The faster of the two trials was taken as the outcome measure.

Fatiguing-inducing session

The BEST (Scanlan, Dascombe, Reaburn, Tucker, & Dalbo, 2014) was used to induce fatigue using a basketball-specific stimulus given the test replicates the movement patterns performed during basketball game-play (Figure 1). Participants completed 2 x 12-min trials of the BEST, with 2 min rest between each trial to represent the average playing time of basketball athletes during game-play (Sampaio, Drinkwater, & Leite, 2010). Heart rate was continuously monitored across the BEST (Polar H10,

Polar RCX3M Run, Polar Electro Oy, China), with a rating of perceived exertion (RPE) taken immediately following the test using a 6-20 scale (Borg, 1982). During the test, participants were required to complete repeated circuits of basketball-specific activity, with each circuit being allotted a 30-s timeframe.

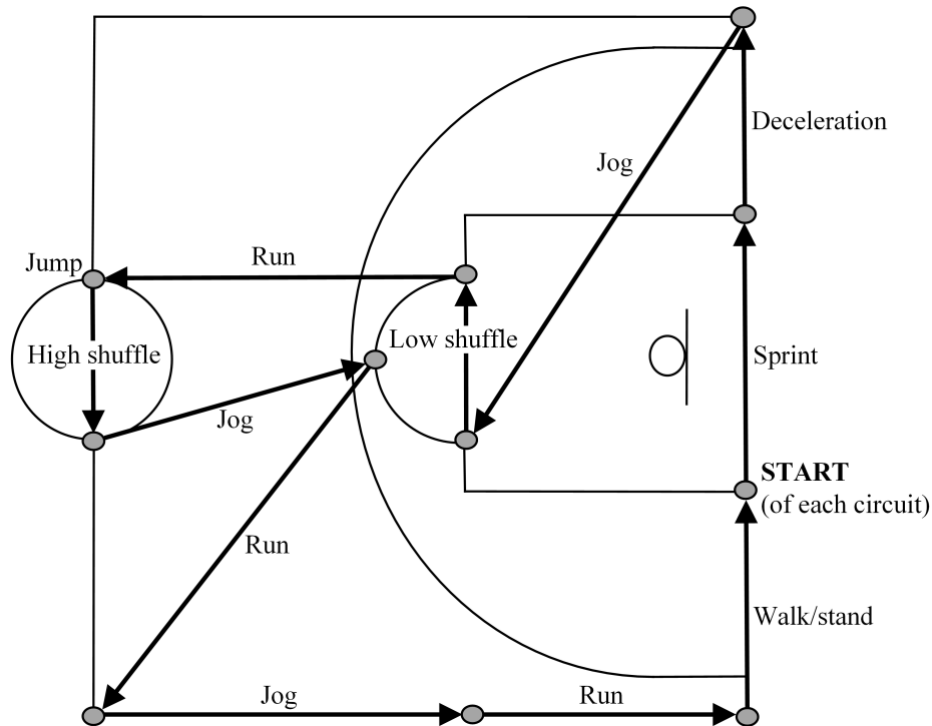


Figure 2. The Basketball Exercise Simulation Test (BEST), adapted from Scanlan et al. (2014).

On completion of the BEST, participants performed four sets of 10 lunge jumps, with a 30-s rest between each set. Finally, participants performed a 2-min isometric wall sit, involving sitting with their backs against a wall, feet flat on the ground, and knees bent at 90°.

Compression garment pressure measurement

The applied pressure of the compression garments was tested using the Kikuhime device (MediGroup, Melbourne, Australia) at the medial malleolus of the ankle, maximal circumference of the calf, and maximal circumference of the thigh. Garment pressure measurements were taken when the garments were first worn and immediately prior to their removal, ~15 hours later. The Kikuhime pressure monitor has been shown to be a valid (ICC = 0.99, CV = 1.1%) and reliable (CV = 4.9%) tool for compression measurement in sports settings (Brophy-Williams, Driller, Halson, Fell, & Shing, 2014).

Sleep monitoring

Sleep duration was monitored using the Mi-band 2 actigraphy device (Foxconn, Xiaomi, China). At 07:30, participants were woken if not already awake, and total sleep duration was recorded. The Mi-Band 2 has been validated previously, with a mean absolute percentage error accuracy of 0.12% reported for sleep duration (Xie et al., 2018). Sleep quality was also recorded in the morning on a 1-5 scale (1 = very poor, 5 = excellent) by each participant.

Statistical analysis

Descriptive statistics are shown as means \pm standard deviations. To examine the efficacy of the fatigue protocol, 2 (condition: CON, COMP) x 2 (time: pre-exercise, post-exercise) factorial ANOVAs were performed for each perceptual rating and performance measure. Absolute change scores were then computed between post-exercise and post-recovery time points for all perceptual ratings and performance measures, also using 2 (condition: CON, COMP) x 2 (time: post-exercise, post-recovery) ANOVA's. Bonferroni post hoc tests were applied if significant effects

were detected. Analysis of the studentised residuals was verified visually with histograms and also by the Shapiro-Wilk test of normality. Separate unpaired samples *t*-tests were used to compare both CON and COMP groups for each of the sleep measures. Effect size statistics were also calculated to determine pairwise differences between COMP and CON groups between post-exercise and post-recovery time points. Specifically, the standardised change in mean, between time points were calculated and expressed as standardised effects (Cohen's *d*) with 95% confidence intervals. The magnitude of each effect size was interpreted using thresholds of 0.2, 0.6, 1.2 and 2.0 for *small*, *moderate*, *large*, and *very large*. An effect size of <0.2 was considered *trivial*. Where the 95% confidence limits overlapped the thresholds for *small* positive and *small* negative values, the effect was considered *unclear*. Statistical analyses were performed using IBM SPSS statistics (Version 22, IBM Corporation, Armonk, NY) and effect sizes were calculated using Microsoft Excel. Statistical significance was set at $p < 0.05$ for all analyses.

Results

Significant main effects of time from pre-exercise to post-exercise were found for all performance measures and perceptual ratings ($p \leq 0.05$), demonstrating increased fatigue and muscle soreness (Figure 3) and reduced physical performance (Table 1) following the exercise protocol.

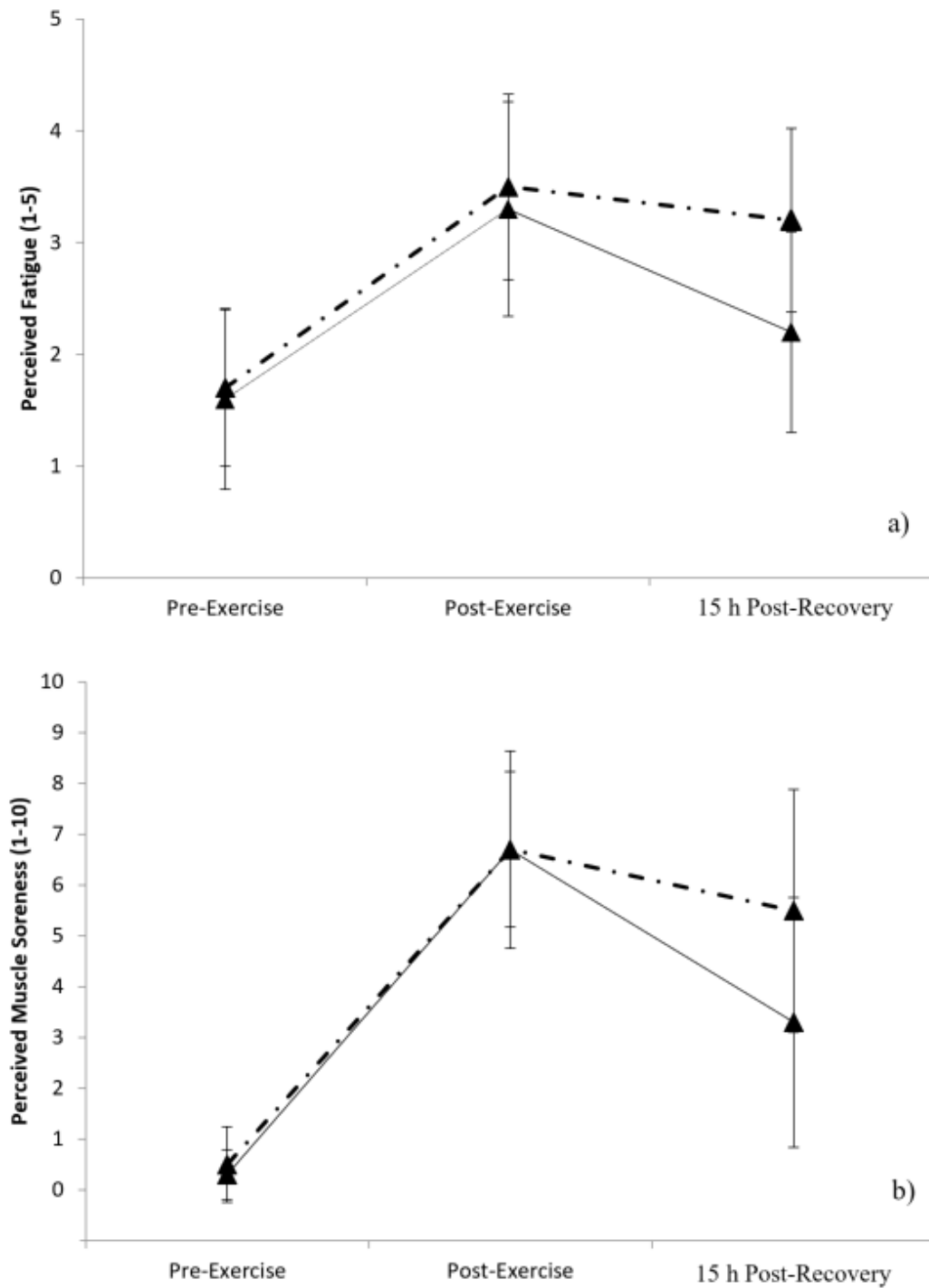


Figure 3. Mean \pm SD a) perceived fatigue (1 = not physically tired at all to 5 = very physically tired) and; b) perceived muscle soreness (1 = no soreness to 10 = extremely sore) pre-exercise, post-exercise, and post-recovery in control (CON – dashed line) and compression (COMP - solid line) conditions.

Table 1. Mean \pm SD for pre-exercise, post-exercise, and post-recovery performance measures for control (CON) and compression (COMP) conditions.

Measure	Condition	Pre-exercise	Post-exercise	Post-recovery
Vertical jump height (Berry & McMurray)	CON	69.8 \pm 7.8	68.6 \pm 9.1	67.2 \pm 8.1
	COMP	67.9 \pm 11.8	66.1 \pm 11.5	65.1 \pm 12.1
Vertical jump impulse (N·s)	CON	1.56 \pm 0.29	1.44 \pm 0.34	1.57 \pm 0.37
	COMP	1.55 \pm 0.36	1.35 \pm 0.27	1.53 \pm 0.40
20-m sprint time (s)	CON	3.25 \pm 0.27	3.32 \pm 0.39	3.39 \pm 0.16
	COMP	3.47 \pm 0.29	3.59 \pm 0.36	3.55 \pm 0.30
Repeated-sprint time (s)	CON	20.41 \pm 0.99	21.37 \pm 1.77	20.79 \pm 0.97
	COMP	21.77 \pm 1.55	22.61 \pm 2.52	21.77 \pm 1.88
Sprint decrement (%)	CON	-4.6 \pm 5.3	-6.9 \pm 8.0	-2.1 \pm 1.0
	COMP	-4.2 \pm 4.2	-4.6 \pm 2.8	-2.2 \pm 1.3
5-0-5 Agility time (s)	CON	2.63 \pm 0.22	2.67 \pm 0.20	2.60 \pm 0.18
	COMP	2.72 \pm 0.23	2.74 \pm 0.26	2.64 \pm 0.19

There was a statistically significant interaction between condition and time for muscle soreness ($F(2, 28) = 184.67$, $p = 0.04$) and perceived fatigue ($F(2,28) = 3.65$, $p = 0.04$). Muscle soreness and perceived fatigue showed *large* differences post-recovery (in the change from post-exercise values) between groups ($d = -1.27$ and $d = -1.61$, respectively) in favour of COMP (Figure 3).

No significant interaction between condition and time was found ($p > 0.05$) for any of the performance measures, suggesting there were negligible differences in performance recovery between COMP and CON. Furthermore, *trivial* or *unclear* differences in performance were evident between groups at all time points (Table 2).

Table 2. Post-recovery comparison of all performance measures and perceptual ratings compared to post-exercise. Data presented as raw difference in values (mean \pm 95% confidence intervals) with effect sizes for comparison between experimental (COMP) and control (CON) groups.

Measure	Post-recovery Δ COMP- Δ CON	
	Raw \pm 95% CI	$d \pm$ 95% CI, <i>interpretation</i>
Vertical jump height (Berry & McMurray)	0.4 \pm 2.1	0.04 \pm 0.20, <i>trivial</i>
Vertical jump impulse (N·s)	0.05 \pm 0.31	0.16 \pm 0.99, <i>unclear</i>
20-m sprint time (s)	-0.12 \pm 0.19	-0.33 \pm 0.53, <i>unclear</i>
Repeated-sprint time (s)	-0.36 \pm 0.80	-0.19 \pm 0.43, <i>unclear</i>
Sprint decrement (%)	-2.3 \pm 3.8	-0.42 \pm 0.68, <i>unclear</i>
5-0-5 Agility time (s)	-0.03 \pm 0.09	-0.11 \pm 0.36, <i>unclear</i>
Fatigue	-1.0 \pm 0.7	-1.27 \pm 0.85, <i>large</i>
Muscle soreness	-2.1 \pm 1.9	-1.61 \pm 1.17, <i>large</i>

Table 3 presents the pressure measurements of the compression garments post-exercise and post-recovery. There were no significant differences in garment pressure across the experimental protocol ($p > 0.05$). Perceived sleep quality, as well as measured sleep duration, are reported in Table 4. *Small* differences in perceived sleep quality ($d = -0.42$, $p = 0.18$) were shown in favour of the COMP group. *Unclear* differences between conditions were found for measured sleep duration ($d = -0.70$, $p = 0.10$).

Table 3. Mean \pm SD pressure measurements (mmHg) for the compression garments at post-exercise and post-recovery.

Time point	Ankle	Calf	Thigh
Post-exercise	7 \pm 3	10 \pm 3	8 \pm 2
Post-recovery	8 \pm 3	10 \pm 2	8 \pm 2

Table 4. Sleep quality and duration for the control (CON) and compression (COMP) groups, with effect sizes between groups $\pm 95\%$ confidence intervals.

Measure	Group	Mean \pm SD	CON-COMP <i>d</i> $\pm 95\%$ CI, <i>interpretation</i>
Perceived sleep quality*	CON	3.4 \pm 1.3	-0.42 \pm 0.49, <i>small</i>
	COMP	4.0 \pm 0.9	
Sleep duration (h:min)	CON	9:50 \pm 0:24	0.70 \pm 1.00, <i>unclear</i>
	COMP	9:25 \pm 0:45	

*Perceived sleep quality measured using a 5-point Likert scale where 1 = very poor and 5 = excellent.

Discussion

This study examined the efficacy of lower-body compression garments worn overnight following basketball-specific, fatigue-inducing exercise on perceived recovery and subsequent performance in recreational basketball athletes. The main findings in this study were that compression garments aided perceptual ratings of fatigue and muscle soreness with *large*, significant improvements compared to the control group. Furthermore, non-significant, *trivial* or *unclear* effects were evident for all performance measures between compression garment and control groups, suggesting a negligible influence on physical performance.

Participants who wore compression garments felt less muscle soreness and fatigue compared to the control group post-recovery in the current study. These findings demonstrate a psychological benefit with compression garments, which has also been shown in other research (Duffield et al., 2010a; Goto, Mizuno, & Mori, 2017; Montgomery, Pyne, Cox, et al., 2008; Pruscino et al., 2013). Collectively, these studies indicate the changes induced in psychological response may be greater than physiological responses when wearing compression garments. In this regard, Duffield et al. (2010a) investigated perceived muscle soreness following fatiguing exercise (sprints and plyometric bounds), showing a significant improvement ($p = 0.01$) when wearing full-length, lower-body compression garments compared to a control condition. Likewise, Pruscino et al. (2013) showed a trend ($p = 0.053$) in favour of compression garments worn during recovery in reducing muscle soreness when worn for 24h after exercise compared to a control condition. Montgomery et al. (2008) also reported *moderate to very large* differences in perceived muscle soreness ($-0.9\% \pm 1.5\%$) and fatigue ($-1.1\% \pm 2.0\%$) throughout a 3-day basketball tournament compared to a control group. These studies are comparable to the current study, which resulted in a *large* difference between groups for the post-exercise to post-recovery change in muscle soreness ($d = -1.61$) in favour of the compression group. Improvements in perceived muscle soreness may be underpinned by increases in circulation and decreases in inflammation with compression, increasing blood lactate removal and reducing space for swelling to occur (Pruscino et al., 2013). However, this mechanism is largely speculative in the current study, and even unlikely given the

low levels of pressure in the garments, indicating a possible placebo effect might have occurred.

Our findings for all performance measures, suggests a limited benefit of compression garments when worn overnight following basketball-specific exercise. These results are in line with previous basketball research (Montgomery, Pyne, Hopkins, et al., 2008) involving lower-body compression garments worn overnight for ~18 hours each day, across a 3-day basketball tournament in sub-elite athletes. Testing was conducted pre- and post-game on each day of the tournament with compression garments resulting in a decrease in 20-m sprint performance ($3.2 \pm 1.6\%$) and vertical jump height ($-6.7 \pm 11.2\%$) which was more detrimental than the control condition ($0.7 \pm 1.3\%$ and $-2.6 \pm 6.6\%$, respectively) (Montgomery, Pyne, Hopkins, et al., 2008). Likewise, Duffield et al. (2010a) investigated the use of lower-body compression garments following an exercise bout of 10 x 20-m sprints and 10 x plyometric bounds every minute for 10 min, where 20-m sprint performance was measured pre, 2h, and 24h after the first exercise bout. Participants wore compression garments during the first bout of exercise and for the subsequent 24h until the final testing was completed. No significant differences ($p = 0.70$) and *small* effects ($d < 0.3$) between control and compression groups were evident across all time points throughout recovery. These results show a similar negligible effect on sprint performance with compression garments to our observations.

Similarly, the effects of compression garments on other performance measures, including vertical jump and change-of-direction speed outcomes in the current study were *unclear*, which aligns with past research in team sport athletes (French et al., 2008; Goto et al., 2017; Montgomery, Pyne, Cox, et al., 2008). For instance, Goto et al. (2017) reported no significant differences between control and compression groups during countermovement and rebound jumps, with the authors concluding insufficient pressures may have been exerted by the compression garments (~8-12 mmHg) with high inter-individual variability (Goto et al., 2017). Similarly, Montgomery, Pyne, Hopkins, et al. (2008) reported negligible effects for compression garments, also suggesting the pressure applied by the garments was not high enough (~18 mmHg) to elicit physiological changes that may aid recovery for jump and change-of-direction

performance. Consequently, the pressure levels exerted by the compression garments in our study may have also been insufficient to induce positive performance effects only reaching mean values of 7-10 mmHg across lower-body landmarks.

Sleep data showed an *unclear* effect for sleep duration between compression garment and control groups, and a *small* effect for perceived sleep quality in favour of compression garments. Previous research showed sleep quality was unaffected when wearing compression garments in male and female participants after a resistance exercise bout (Kraemer et al., 2010b); however, the compression garments worn in their study were full-body suits, which may elicit greater discomfort than lower-body garments when worn overnight. In the current study, it is possible that the reduced muscle soreness in the compression group was related to the enhanced perceived sleep quality encountered. Indeed, previous research has shown that pain may interfere with sleep (Wittig, Zorick, Blumer, Heilbronn, & Roth, 1982). When it comes to muscle soreness or pain, there is potential for an increased activation of neurons that transmit nociceptive signals, and activate regions of the brain involved in the regulation of sleep (Mense, 1993). Further research on muscle soreness and sleep are warranted in the exercise recovery setting.

Despite the novel approach to examining the perceptual and performance effects of lower-body compression garments worn during recovery in basketball athletes, there were some important limitations that should be acknowledged. First, the use of a randomised, counter-balanced, cross-over design was preferable; however, this approach was not feasible in the present study due to logistical constraints. Second, the lack of a placebo group meant that psychological factors could potentially elicit a confounding effect on the results obtained. While it is difficult to design a placebo garment in compression studies, perhaps an alternative placebo recovery strategy could have been implemented. Indeed, it has been shown previously that belief in the benefit of compression garments may positively influence results (Brophy-Williams et al., 2017). Third, compression levels were lower than expected in the current study (~10 mmHg), as participants used the recommended sizing for garments provided by the manufacturer. Perhaps a smaller-sized garment than what is recommended should have been used to ensure a higher pressure was applied (ideally >20 mmHg). While

the optimal pressure of compression garments is yet to be determined, Liu and colleagues (2008) suggested that a pressure of ≥ 18 mmHg was required to instigate positive responses in haemodynamics, while Bochmann and colleagues (2005) recommended pressure ≥ 20 mmHg to increase limb blood flow, but this is yet to be extensively explored in athletic populations.

In conclusion, wearing of lower-body compression garments overnight following basketball-specific fatiguing exercise improved perceived muscle soreness and fatigue, but did not restore various performance measures more effectively than a control condition in recreational basketball athletes. Perhaps relatedly, there were *small* benefits to perceived sleep quality when wearing lower-body compression garments. Based on these results, we would recommend that recreational basketball athletes may benefit from the use of lower-body compression garments to reduce muscle soreness and fatigue, which may enhance subsequent sleep quality. These findings may have practical applications to recreational populations in promoting daily activity and exercise levels.

**Chapter 3: Summary, Limitations, Practical Applications
and Further Research Directions**

Summary

Overall the results from the original research included in chapter 2 showed psychological measures had the greatest benefit from the use of compression garments in recovery following basketball exercise. Performance measures showed little benefit from wearing compression garments. Conclusions from this study are that compression garment use over 15h will improve perceived sleep quality and perceived muscle soreness, but further research should be conducted to investigate the effects on performance measures in basketball athletes.

Limitations

- The lack of a placebo group meant that participants could not be blinded to the condition group they were a part of. Therefore participants knew which condition group they were apart of which meant the psychological results could potentially have an influence on the results.
- A cross-over counterbalanced study design would have been the preferred method of testing but this was not feasible in the current study. A crossover design would have matched the results of the compression condition for the participants against their own control results giving a more accurate comparison.
- The applied pressure was lower than expected (~10mmHg), as participants wore the recommended size provided by the manufacturer. Therefore, the applied pressure may not have been high enough to elicit an effect on the participants. The preferred level of pressure would ideally be >20mmHg,

which meant the participants needed to wear a smaller size than the manufacturers' recommendations.

Practical Applications

Following the use of compression garments worn overnight for recovery following fatiguing exercise, recreational athletes may; perceive lower levels of muscle soreness, have a better night of sleep, feel better rested and less fatigued than when wearing normal clothes. This may influence recreational athletes to participate in activity more regularly, as they do not feel as sore or as tired. However, wearing compression garments with the pressure levels in the current thesis (~10 mmHg) is unlikely to result in any performance improvements the following day, when assessing measures of speed/acceleration, agility, and jumping. In comparison, previous research using higher levels of applied pressure (≥ 18 mmHg) have found benefits from the use of compression garments such as increased limb blood flow, increased creatine kinase clearance, and improved strength and power. Thus warranting further research in the area.

Further Research Direction

- Future research should aim to evaluate the effects of different pressure levels on the participant to determine the optimal pressure level for the use in sports recovery.
- Future research should include higher-level (elite or professional) athletes in basketball to investigate the different needs for compression. Effects of compression on higher-level athletes may differ from recreational athletes as they are accustomed to consecutive day training, high levels of muscle

damage and fatigue and may require a higher level of compression, or require shorter or longer time wearing compression to elicit any effects.

- Future studies should comprise of a crossover, counterbalanced design with the inclusion of a placebo group and/or the inclusion of multiple different types of recovery techniques, such as cold-water immersion and active recovery.
- Future research should also aim to investigate the optimal time for compression garments to be worn, by testing the same garments (eliciting the same pressure levels) worn for different time periods.

References

- Ali, A., Caine, M. P., & Snow, B. G. (2007). Graduated compression stockings: Physiological and perceptual responses during and after exercise. *Journal of Sports Sciences*, 25(4), 413-419. <http://doi.org/10.1080/02640410600718376>
- Atkins, W. A. (2012). Basketball. In J. L. Longe. (Ed.), *The Gale encyclopedia of fitness*. (1st ed.). Farmington, MI: Retrieved from <http://ezproxy.waikato.ac.nz/login?url=https://search.credoreference.com/content/entry/galefit/basketball/0?institutionId=781>.
- Beliard, S., Chauveau, M., Moscatiello, T., Cros, F., Ecarnot, F., & Becker, F. (2014). Compression garments and exercise: No influence of pressure applied. *Journal of Sports Science and Medicine*, 14(1), 75-83.
- Berry, M., & McMurray, R. (1987). Effects of graduated compression stockings on blood lactate following an exhaustive bout of exercise. *American Journal of Physical Medicine*, 66(3), 121-132.
- Bochmann, R. P., Seibel, W., Haase, E., Hietschold, V., Rodel, H., & Deussen, A. (2005). External compression increases forearm perfusion. *Journal of Applied Physiology*, 99(6), 2337-2344.
- Borg, G. A. (1982). Psychophysical bases of perceived exertion. *Medicine & Science in Sports & Exercise*, 14(5), 377-381.
- Brophy-Williams, N., Driller, M., Kitic, C., Fell, J., & Halson, S. (2017). Effect of compression socks worn between repeated maximal running bouts. *International Journal of Sports Physiology and Performance*, 12(5), 621-627. <http://doi.org/10.1123/ijsp.2016-0162>
- Brophy-Williams, N., Driller, M. W., Halson, S. L., Fell, J. W., & Shing, C. M. (2014). Evaluating the kikuhime pressure monitor for use with sports compression clothing. *Sports Engineering*, 17(1), 55-60. <http://doi.org/10.1007/s12283-013-0125-z>
- Brown, F., Gissane, C., Howatson, G., van Someren, K., Pedlar, C., & Hill, J. (2017). Compression garments and recovery from exercise: A meta-analysis. *Sports Medicine*, 47(11), 2245-2267. <http://doi.org/10.1007/s40279-017-0728-9>
- Chatard, J. C., Atlaoui, D., Farjanel, J., Louisy, F., Rastel, D., & Guézenec, C. Y. (2004). Elastic stockings, performance and leg pain recovery in 63-year-old sportsmen. *European Journal of Applied Physiology*, 93(3), 347-352. <http://doi.org/10.1007/s00421-004-1163-9>
- Chatzinikolaou, A., Draganidis, D., Avloniti, A., Karipidis, A., Jamurtas, A. Z., Skevaki, C. L., Kambas, A. (2014). The microcycle of inflammation and performance changes after a basketball match. *Journal of Sport Sciences*, 32(9), 870-882.
- Crisafulli, A., Melis, F., Laconi, F., Lai, P., Concu, C., Tocco, A., & Concu, A. (2002). External mechanical work versus oxidative energy consumption ratio during a basketball field test. *Journal of Sports Medicine and Physical Fitness*, 42(4), 409-417.
- Davies, V., Thompson, K., & Cooper, S.-M. (2009). The effects of compression garments on recovery. *Journal of Strength and Conditioning Research*, 23(6), 1786-1794.
- Driller, M., & Brophy-Williams, N. (2016). *The Use of Compression Garments in Elite Australian Athletes: A Survey* (Vol. 5).

- Duffield, R., Cannon, J., & King, M. (2010a). The effects of compression garments on recovery of muscle performance following high-intensity sprint and plyometric exercise. *Journal of Science and Medicine in Sport*, *13*(1), 136-140. <http://doi.org/10.1016/j.jsams.2008.10.006>
- Duffield, R., Cannon, J., & King, M. (2010b). The effects of compression garments on recovery of muscle performance following high-intensity sprint and plyometric exercise. *Journal of Science and Medicine in Sport*, *13*(1), 136-140. <http://doi.org/10.1016/j.jsams.2008.10.006>
- Duffield, R., & Portus, M. (2007). Comparison of three types of full-body compression garments on throwing and repeat-sprint performance in cricket players. *British Journal of Sports Medicine*, *41*(7), 409. <http://doi.org/10.1136/bjsm.2006.033753>
- French, D. N., Thompson, K. G., Garland, S. W., Barnes, C. A., Portas, M. D., Hood, P. E., & Wilkes, G. (2008). The effects of contrast bathing and compression therapy on muscular performance. *Medicine and Science in Sports and Exercise*, *40*(7), 1297-1306. <http://doi.org/10.1249/MSS.0b013e31816b10d5>
- Gill, N. D., Beaven, C. M., & Cook, C. (2006). Effectiveness of post-match recovery strategies in rugby players. *British Journal of Sports Medicine*, *40*(3), 260. <http://doi.org/10.1136/bjsm.2005.022483>
- Goto, K., Mizuno, S., & Mori, A. (2017). Efficacy of wearing compression garments during post-exercise period after two repeated bouts of strenuous exercise: a randomized crossover design in healthy, active males. *Sports Medicine - Open*, *3*(1), 25. <http://doi.org/10.1186/s40798-017-0092-1>
- Hamlin, M. J., Mitchell, C. J., Ward, F. D., Draper, N., Shearman, J. P., & Kimber, N. E. (2012). Effect of compression garments on short-term recovery of repeated sprint and 3-km running performance in rugby union players. *Journal of Strength and Conditioning Research*, *26*(11), 2975-2982. <http://doi.org/10.1519/JSC.0b013e3182711e0b>
- Hill, J., Howatson, G., Gaze, D., Legg, H., Lineham, J., & Pedlar, C. (2017). The effects of compression-garment pressure on recovery after strenuous exercise. *International Journal of Sports Physiology and Performance*, *12*(8), 1078-1084. <http://doi.org/10.1123/ijsp.2016-0380>
- Jakeman, J., Byrne, C., & Eston, R. (2010). Lower limb compression garment improves recovery from exercise-induced muscle damage in young, active females. *European Journal of Applied Physiology*, *109*(6), 1137-1144. <http://doi.org/10.1007/s00421-010-1464-0>
- Kraemer, W. J., Bush, J. A., Wickham, R. B., Denegar, C. R., Gómez, A. L., Gotshalk, L. A., & Sebastianelli, W. J. (2001). Influence of compression therapy on symptoms following soft tissue injury from maximal eccentric exercise. *Journal of Orthopaedic & Sports Physical Therapy*, *31*(6), 282-290. <http://doi.org/10.2519/jospt.2001.31.6.282>
- Kraemer, W. J., Flanagan, S. D., Comstock, B. A., Fragala, M. S., Earp, J. E., Dunn-Lewis, C., & Maresh, C. M. (2010a). Effects of a whole body compression garment on markers of recovery after a heavy resistance workout in men and women. *Journal of Strength and Conditioning Research*, *24*(3), 804-814. <http://doi.org/10.1519/JSC.0b013e3181d33025>
- Kraemer, W. J., Flanagan, S. D., Comstock, B. A., Fragala, M. S., Earp, J. E., Dunn-Lewis, C., & Maresh, C. M. (2010b). Effects of a whole body compression garment on markers of recovery after a heavy resistance workout in men and

- women. *Journal of Strength and Conditioning Research*, 24(3), 804-814.
<http://doi.org/10.1519/JSC.0b013e3181d33025>
- Lee, D. C. W., Lee, S. W. Y., Khaw, K., Ali, A., Sheridan, S. E., & Wong, S. H. S. (2018). Haemodynamic responses of wearing low-pressure sports compression tights during an orthostatic challenge in healthy individuals. *Journal of Science and Medicine in Sport*, 21(10), 1062-1067.
<http://doi.org/10.1016/j.jsams.2017.12.004>
- Liu, R., Lao, T. T., Kwok, Y. L., Li, Y., & Ying, M. T. (2008). Effects of graduated compression stockings with different pressure profiles on lower-limb venous structures and haemodynamics. *Advances in Therapy*, 25(5), 465-478.
<http://doi.org/10.1007/s12325-008-0058-2>
- MacRae, B., Cotter, J., & Laing, R. (2011). Compression garments and exercise. *Sports Medicine*, 41(10), 815-843. <http://doi.org/10.2165/11591420-000000000-00000>
- MacRae, B. A., Laing, R. M., & Partsch, H. (2016). General considerations for compression garments in sports: Applied pressures and body coverage. In *Compression garments in sports: Athletic performance and recovery* (pp. 1-32). https://doi.org/10.1007/978-3-319-39480-0_1
- Marqués-Jiménez, D., Calleja-González, J., Arratibel, I., Delextrat, A., & Terrados, N. (2016). Are compression garments effective for the recovery of exercise-induced muscle damage? A systematic review with meta-analysis. *Physiology & Behavior*, 153, 133-148. <http://doi.org/10.1016/j.physbeh.2015.10.027>
- Mattacola, C. G., Perrin, D. H., Gansneder, B. M., Allen, J. D., & Mickey, C. A. (1997). A comparison of visual analog and graphic rating scales for assessing pain following delayed onset muscle soreness. *Journal of Sport Rehabilitation*, 6(1), 38-46. <http://doi.org/10.1123/jsr.6.1.38>
- Ménérier, A., Pinot, J., Mourot, L., Grappe, F., Bouhaddi, M., Regnard, J., & Tordi, N. (2013). Effects of recovery using contrast water therapy or compression stockings on subsequent 5-min cycling performance. *Journal of Science and Cycling*, 2(2), 49-56.
- Mense, S. (1993). Nociception from skeletal muscle in relation to clinical muscle pain. *Pain*, 54(3), 241-289.
- Montgomery, P. G., Pyne, D. B., Cox, A. J., Hopkins, W. G., Minahan, C. L., & Hunt, P. H. (2008). Muscle damage, inflammation, and recovery interventions during a 3-day basketball tournament. *European Journal of Sport Science*, 8(5), 241-250. <http://doi.org/10.1080/17461390802251844>
- Montgomery, P. G., Pyne, D. B., Hopkins, W. G., Dorman, J. C., Cook, K., & Minahan, C. L. (2008). The effect of recovery strategies on physical performance and cumulative fatigue in competitive basketball. *Journal of Sports Sciences*, 26(11), 1135-1145.
<http://doi.org/10.1080/02640410802104912>
- Perrey, S., Bringard, A., Racinais, S., Puchaux, K., Belluye, N., Estivalet, M., & Brisson, (2008). Graduated Compression Stockings and Delayed Onset Muscle Soreness (P105). In *The Engineering of Sport 7*. (Vol.1, pp 547-554).
http://doi.org/10.1007/978-2-287-09411-8_64
- Pruscino, C., Halson, S., & Hargreaves, M. (2013). Effects of compression garments on recovery following intermittent exercise. *European Journal of Applied Physiology*, 113(6), 1585-1596. <http://doi.org/10.1007/s00421-012-2576-5>
- Randers, M. B., Hagman, M., Brix, J., Christensen, J. F., Pedersen, M. T., Nielsen, J. J., & Krstrup, P. (2018). Effects of 3 months of full-court and half-court

- street basketball training on health profile in untrained men. *Journal of Sport and Health Science*, 7(2), 132-138.
- Sallet, P., Perrier, D., Ferret, J., Vitelli, V., & Baverel, G. (2005). Physiological differences in professional basketball players as a function of playing position and level of play. *Journal of Sports Medicine and Physical Fitness*, 45(3), 291-294.
- Sampaio, J., Drinkwater, E. J., & Leite, N. M. (2010). Effects of season period, team quality, and playing time on basketball players' game-related statistics. *European Journal of Sport Science*, 10(2), 141-149. <http://doi.org/10.1080/17461390903311935>
- Scanlan, A., Dascombe, B., Reaburn, P., Tucker, P., & Dalbo, V. (2014). The development of the basketball exercise simulation test. *Journal of Science and Medicine in Sport*, 9(13), 700-712. <http://doi.org/10.14198/jhse.2014.93.03>
- Scanlan, A. T., Dascombe, B. J., Kidcaff, A. P., Peucker, J. L., & Dalbo, V. J. (2015). Gender-specific activity demands experienced during semiprofessional basketball game play. *International Journal of Sports Physiology and Performance*, 10(5), 618-625.
- Spencer, M., Fitzsimons, M., Dawson, B., Bishop, D., & Goodman, C. (2006). Reliability of a repeated-sprint test for field-hockey. *Journal of Science and Medicine in Sport*, 9(1-2), 181-184.
- Sperlich, B., & Holmberg, H.-C. (2013). Bringing light into the dark: Effects of compression clothing on performance and recovery. *International Journal of Sports Physiology and Performance*, 8(1), 4-18. <http://doi.org/10.1123/ijsp.8.1.4>
- Stojanović, E., Stojiljković, N., Scanlan, A. T., Dalbo, V. J., Berkelmans, D. M., & Milanović, Z. (2018). The activity demands and physiological responses encountered during basketball match-play: a systematic review. *Sports Medicine*, 48(1), 111-135.
- Tavares, F., Healey, P., Smith, T. B., & Driller, M. (2017). The usage and perceived effectiveness of different recovery modalities in amateur and elite Rugby athletes. *Performance Enhancement & Health*, 5(4), 142-146. <http://doi.org/10.1016/j.peh.2017.04.002>
- Troynikov, O., Ashayeri, E., M, B., Subic, A., Alam, F., & Marteau, S. (2010). Factors influencing the effectiveness of compression garments used in sports. *Procedia Engineering*, 2(2), 2823-2829. <http://doi.org/10.1016/j.proeng.2010.04.073>
- Upton, C., Brown, F., & Hill, J. (2017). Efficacy of compression garments on recovery from a simulated rugby protocol. *Journal of Strength and Conditioning Research*, 31(11), 2977. <http://doi.org/10.1519/JSC.0000000000002145>
- Watanuki, S., & Murata, H. (1994). Effects of wearing compression stockings on cardiovascular responses. *The Annals of physiological anthropology*, 13(3), 121-127. <http://doi.org/10.2114?ahs1983.13.121>
- Wen, N., Dalbo, V. J., Burgos, B., Pyne, D. B., & Scanlan, A. T. (2018). Power testing in basketball: Current practice and future recommendations. *Journal of Strength and Conditioning Research*, 32(9), 2677-2691.
- Wittig, R. M., Zorick, F. J., Blumer, D., Heilbronn, M., & Roth, T. (1982). Disturbed sleep in patients complaining of chronic pain. *The Journal of Nervous and Mental Disease*, 170(7), 429-431.

- Xie, J., Wen, D., Liang, L., Jia, Y., Gao, L., & Lei, J. (2018). Evaluating the validity of current mainstream wearable devices in fitness tracking under various physical activities: Comparative study. *JMIR mHealth and uHealth*, 6(4). <http://doi.org/10.2196/mhealth.9754>
- Xiong, Y., & Tao, X. (2018). Compression garments for medical therapy and sports. *Polymers*, 10(6). <http://doi.org/10.3390/polym10060663>

Appendices

Appendix 1: Ethics Approval

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

Human Research Ethics Committee
Julie Barbour
Telephone: +64 7 838 9336
Email: julie.barbour@waikato.ac.nz



31st May 2017

Rebecca Atkins and Zanz Dixon
Dr. Matt Driller

Dear Rebecca and Zanz,

UoW HREC(Health)#2017-17: The effects of compression garments on performance and recovery in basketball athletes

Thank you for submitting your amended application for ethical approval. We are now pleased to provide formal approval for your randomized crossover study of 15 to 30 premier basketball players including:

- A familiarization trial of all testing procedures
- Experimental (recovery) trial
- 12-hours post recovery testing
- Control trial
- 12-hours post recovery testing
- Experimental (exercise) trial

Please contact the committee 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: PAR-Q

Physical Activity Readiness Questionnaire (PAR-Q)

Regular physical activity is fun and healthy, and increasingly more people are starting to become more active every day. Being more active is very safe for most people. However, some people should check with their doctor before they start becoming much more physically active.

If you are planning to become much more physically active than you are now, start by answering the seven questions in the box below. If you are between the ages of 15 and 69, the PAR-Q will tell you if you should check with your doctor before you start. If you are over 69 years of age, and you are not used to being very active, check with your doctor.

Common sense is your best guide when you answer these questions. Please read the questions carefully and answer each one honestly: check YES or NO.

YES	NO	
<input type="checkbox"/>	<input type="checkbox"/>	1. Has your doctor ever said that you have a heart condition <u>and</u> that you should only do physical activity recommended by a doctor?
<input type="checkbox"/>	<input type="checkbox"/>	2. Do you feel pain in your chest when you do physical activity?
<input type="checkbox"/>	<input type="checkbox"/>	3. In the past month, have you had chest pain when you were not doing physical activity?
<input type="checkbox"/>	<input type="checkbox"/>	4. Do you lose your balance because of dizziness or do you ever lose consciousness?
<input type="checkbox"/>	<input type="checkbox"/>	5. Do you have a bone or joint problem (for example, back, knee or hip) that could be made worse by a change in your physical activity?
<input type="checkbox"/>	<input type="checkbox"/>	6. Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?
<input type="checkbox"/>	<input type="checkbox"/>	7. Do you know of <u>any other reason</u> why you should not do physical activity?