**The Efficacy of Compression Garments on Recovery from a Simulated Rugby Protocol**

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***ABSTRACT***

The aim of this study was to examine the efficacy of lower limb compression garments on recovery in club level rugby players. Nineteen participants (age, 20.3 ± 1.7 years, height, 184.2 ± 7.5 cm and body mass, 89.5 ± 9.9 kg) completed a rugby specific, muscle damaging protocol before being assigned to a compression garment group (n = 10) or a SHAM (“recovery” drink) treatment (n = 9). The compression group wore the garments for 48 h post-exercise, while SHAM consumed a sweetened, low energy drink within an hour of protocol completion. Perceived muscle soreness (PMS), Creatine Kinase (CK), maximal voluntary isometric contraction (MVIC) and countermovement jump height (CMJ) were measured at baseline, post, 24 and 48 h post-exercise. Perceived muscle soreness was significantly lower in the compression group compared to SHAM at both 24 and 48 h post-exercise (*p* ≤ 0.05). The compression group was also subject to lower CK values than SHAM, as demonstrated by a significant time by group effect (*p* ≤ 0.05). There was no significant group effect for MVIC or CMJ (*p* ˃ 0.05). Wearing compression garments following a rugby specific, muscle damaging protocol appears to reduce PMS and circulating concentrations of CK, suggesting improved recovery from muscle damaging exercise.

*Key words: Exercise, muscle damage, team sports, physiology,* *delayed onset muscle soreness*

***INTRODUCTION***

Strenuous physical activity, particularly that which includes an appreciable eccentric component, can lead to the experience of exercise induced muscle damage (6, 7).  Such muscle damage is characterised by a number of symptoms which impair performance, including delayed onset muscle soreness (DOMS), a reduction in force production, and inflammation (6, 8). In order to minimise the negative effects associated with muscle damage, the use of recovery interventions is becoming increasingly popular amongst athletes. One such strategy is the use of compression garments (5, 20).

Compression garments, characterised by their tight fitting, and elastic properties, have been reported to alleviate a number of medical conditions including oedema, deep vein thrombosis and venous insufficiency (23, 29). They have become a preferred treatment over mechanical and pharmacological methods due to their low cost and ease of use (1). Furthermore, compression garments have been demonstrated to accelerate the recovery of strength and power in athletes (24, 27). Accordingly, the use of compression garments is becoming increasingly popular in sport.

Studies have demonstrated improved recovery with the use of compression garments in a variety of sporting domains (1, 2, 20, 24). It is thought that the garments create an external pressure gradient, limiting the space available for swelling to occur and thus reducing swelling and soreness (11, 26). In addition, it has also been suggested that compression garments can modulate blood flow and potentially accelerate the removal of waste products (11).

After a bout of muscle damage, recovery can take up to 4-5 days (9), potentially limiting training intensity and competition performance (3). Training and playing up to 40 weeks of the year, rugby union players require strength and power for optimal performance, while a high volume of anaerobic work and frequent impacts, subsequently results in muscle damage (10). The use of compression could be a valuable aid to recovery in this population.

Whilst several studies have found beneficial effects on recovery with the use of compression garments (14, 24), few studies have investigated the effects of compression on recovery from rugby. As recovery demands will be highly specific to the modality of exercise and requirements of subsequent performance measures (3), there is a need to assess the efficacy of compression garments for recovery from rugby specific exercise. For example, while Gill et al. (16) investigated the efficacy of compression in a group of elite male rugby players following match-play, only the recovery of CK was assessed. Although the significant benefits reported from compression garments do provide some evidence to support their use, these findings need to be interpreted with caution. Creatine kinase was analysed from transdermal exudate, a method yet to be validated, whilst no performance measures were taken. In contrast, Duffield et al (13) observed no differences in recovery with the use of compression following a simulated team game. Differences in findings are likely to be a result of the wide variation in exercise modalities used in each study, as well as variation in populations, types of garments and duration of application (19). Therefore, the aim of this study was to evaluate the efficacy of compression garments for the recovery of strength, power and indices of muscle damage from a rugby specific, muscle damaging protocol.

***METHODS***

**Experimental approach to the problem**

To evaluate the effects of compression on recovery, a compression garments group was compared to controls using a (2 way) mixed measures design. Within subject differences in performance and markers of muscle damage were compared over time between groups, taking measures at baseline, immediately after, then at 24 and 48 h following a rugby-specific muscle damaging protocol. Performance measures were chosen to demonstrate the recovery of rugby specific performance, including lower body strength, as shown by maximal voluntary isometric contraction (MVIC), and lower body power (countermovement jump height). Participants were matched for body weight and then randomly assigned to receive either lower limb compression tights (2XU, MA1551B, men’s compression tights, Melbourne, Australia – Figure 1) or a single serving of a (SHAM) “recovery” drink (Robinsons no added sugar, fruit juice), which contained 1 g carbohydrate and 0 g protein per serving.

**Subjects**

Nineteen club level male rugby union players volunteered to participate in the study, approved by St Marys Ethics Committee in accordance with the Declaration of Helsinki (participant characteristics reported in Table 1). After being given written and verbal explanations of the procedures, risks and benefits of taking part in the study, all participants completed a health screening questionnaire before giving written informed consent. All participants had been playing competitively for at least two years, and were training twice per week in addition to playing weekly matches in the lead up to testing. Participants were asked to refrain from heavy exercise and alternative recovery strategies in the 48 h before protocol commencement. Participants were also asked to refrain from taking any performance related supplements in the 7 days leading up to testing.

**Table 1:** Participant characteristics. Values are means ± SD.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Group | Age (y) | Mass (kg) | Height (cm) | Sum of 8 skinfolds (mm) |
| Compression (n=10) | 20.8 ± 1.9 | 90.4 ± 10.5 | 184.2 ± 7.4 | 120.17 ± 47.6 |
| SHAM (n=9) | 20.4 ± 1.5 | 88.4 ± 9.9 | 183.4 ± 9.2 | 83.1 ± 23.4 |



**Figure 1:** The lower limb compression tights used in the study (2XU, MA1551B, men’s compression tights, Melbourne, Australia)

**Procedures**

Seven days before testing, participants were invited to the laboratories for familiarisation and baseline data collection. Participants reported to the laboratories at the same time of day throughout the duration of the experiment, with all testing occurring between eight and eleven o’clock in the morning. Testing occurred throughout February, during the competitive season. Subjects were requested to record their dietary intake before the first day of testing and replicate for all subsequent days. Players were also encouraged to arrive to the laboratory in a hydrated state after being advised to monitor urine colour to guide drinking practises.

All participants completed a muscle damaging, rugby specific protocol on the university rugby pitch, which simulated match play. The protocol consisted of 20 maximal 20 m sprints with a 10 m deceleration. Every other sprint finished with a tackle bag “slam” (Centurion Rugby Tackle Bag, North Yorkshire, United Kingdom), replicating rugby specific movements which required participants to squat, pick up the bag and slam it on the floor. These drills were completed every minute on a rolling clock. Participants had the remainder of the minute to walk back to the starting line and get ready to repeat the procedure. Immediately after the protocol, participants showered before either putting on compression garments or consuming the (SHAM) recovery drink. This was completed within an hour of exercise. Participants in the compression group wore the garments for 48 h post exercise, removing them only to wash. The degree of compression was measured using a pressure monitor, (Kikukime; TT Medi Trade, Soleddet, Denmark). Garment pressure was measured on the medial site of the calf at the point of maximal girth, and at the front-thigh, situated half way between the inguinal crease and top of the patella. The anatomical measurements were consistent with prior research (20). Within an hour of exercise completion, subjects reported to the laboratory for post exercise testing. Creatine kinase, perceived muscle soreness (PMS), countermovement jump height (CMJ) and MVIC were measured and recorded, before being subsequently re-tested at 24 and 48 h post-exercise. Creatine kinase was analysed from a fingertip capillary blood samples, consistent with prior research (24). Within an hour of blood collection the sample was spun at 4000 rpm for 5 minutes in an Eppendorf 545C centrifuge to ensure separation of plasma serum (Eppendorf UK, Ltd, Histon, Cambridge, UK). The separated serum was then frozen at -80º and later analysed using the RX Monza Clinical Analyser, (Randox Teoranta, Co. Donegal, Republic of Ireland). Perceived muscle soreness was assessed using a visual scale, with 10 representing unbearable pain and 0 indicating no pain at all. Assessment involved participants performing a squat at 90 degrees for 3 seconds before PMS was recorded. Jump height was recorded as the highest CMJ from 3 attempts, using a jump mat (FLS electronics, co Tyrone, UK). Countermovement jumps were performed by performing a deep squat with hands on hips before giving a maximal effort. A strain gauge was used to measure MVIC (MIE Medical Research Ltd., Leeds, United Kingdom). Participants were asked to sit on a platform with both hip and knee joints flexed at 90 degrees, the strain gauge was attached 2cm above the malleoli of the left ankle. Participants were asked to maximally extend the knee against the device for 3 seconds, performing three maximal attempts with the best result recorded, comparable to prior research (21). Calculated intraclass correlation coefficients (ICCs) demonstrated excellent reliability for MVIC (ICC = 0.91, 95% CI = 0.82-0.96) and CMJ (ICC = 0.89, 95% CI = 0.78-0.95), with CK analysis (ICC = 0.49, 95% CI = 0.24-0.74) showing moderate reliability.

**Statistical Analyses**

An independent samples t-test was used to compare group characteristics for all baseline measures. Dependent variables were analysed using a repeated measures ANOVA. Maulchy’s test of sphericity was applied to ascertain homogeneity of variance amongst groups. Where violations of the assumption of sphericity occurred, the Greenhouse-Geisser correction was applied. Where a significant effect was determined, a Bonferroni *post hoc* analysis was run to establish where differences lay. Statistics were analysed using SPSS statistics (SPSS statistics, IBM United Kingdom Ltd. Hampshire, UK) with alpha set at *p* ˂ 0.05. Jump height and MVIC were expressed as percentages of baseline values, to account for inter-individual variation. Data are presented as means ± SD.

***RESULTS***

Compression pressures were measured for all individuals who wore the garments. Mean garment pressure on the calf was 14 ± 4.1 mmHg and mean pressure on the front thigh was 8.5 ± 2.3 mmHg.

There was no significant group difference at baseline for any variable (*P <* 0.05). Following the muscle damaging protocol, the use of compression garments led to no significant group effect, or time-group interaction, for CMJ (F(1) = 0.11, *p =* 0.917; F(1.673) = 1.619, *p =* 0.217) or MVIC (F(3) = 0.24, *p =* 0.995; F(3) = 0.327, *p =* 0.806).

Creatine kinase was subject to a significant change over time (F(3, 1) = 5.805, *p* ≤ 0.002) and a significant group effect, (F(1) = 5.187, *p* ˂ 0.05), with those in the compression garment group experiencing lower levels in comparison to SHAM. However, a *post hoc* Bonferroni test failed to identify where significance lay with respect to time (Figure 2).

Perceived muscle soreness also displayed a significant change over time (F(1.772, 1) = 151.660, *p* ≤ 0.001) and a significant group effect (F(1) = 61.714, *p* ≤ 0.001). Those in the compression group experienced a reduction in muscle soreness in comparison to SHAM. A *post hoc* Bonferroni test revealed that this difference occurred at 24 and 48 h post exercise protocol (Figure 3).

The greatest reduction in MVIC occurred within the SHAM group, with a reduction of 8 % from baseline (92 ± 17 %) occurring at 48 h post-exercise. This was in contrast to the compression group, in which muscular strength increased to 113.1 % of baseline (± 30.4 %) at 48 h. However, this between-group difference was not significant (F(1) = 0.57, *p* ≥ 0.05, Table 2). Similarly, there was no significant difference in CMJ between the two groups (F(1) = 0.11, *p* ≥ 0.05 Table 2).

**Figure 2:** Creatine kinase values for both compression and SHAM groups before and after the muscle damaging protocol. Values are means ± standard deviation. Grey line and square markers = SHAM; Black line and diamond markers = compression garments; # Indicates a significant between-group difference over time

**Figure 3:** Perceived muscle soreness for both compression and SHAM groups before and after the muscle damaging protocol. Values are means ± standard deviations. Grey line and square markers = SHAM; Black line and diamond markers = compression garments; Asterisks indicate significantly reduced soreness in the compression group compared to SHAM (*p <* 0.001)

**Table 2:** Percentage change from baseline measures for jump height and MVIC for both compression and SHAM groups before and after the muscle damaging protocol. Values are given as means ± standard deviation.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Pre | Post | 24 h | 48 h |
| Jump height (%) |  |  |  |  |
| Compression | 100 ± 0 | 105.4 ± 17.3 | 99.7 ± 11.8 | 100.6 ± 12.9 |
| SHAM | 100 ± 0 | 97.5 ± 7.6 | 79.7 ± 20 | 100.2 ± 6.8 |
| MVIC (%) |  |  |  |  |
| Compression | 100 ± 0 | 94.9 ± 22.5 | 97.9 ± 35.6 | 113.1 ± 30.4 |
| SHAM | 100 ± 0 | 89.1 ± 10.8 | 104.4 ± 9.0 | 92 ± 17.0 |

***DISCUSSION***

The aim of the study was to investigate the effect of lower limb compression garments on recovery from muscle damage following rugby-specific exercise. The findings showed that those in the compression group were subject to significant reductions in perceived muscle soreness and circulating CK concentrations compared to SHAM. No significant group differences were reported for MVIC and CMJ.

One of the main observations in this study was the significant difference between groups for CK. Creatine kinase is frequently used as an indirect measure for exercise induced muscle damage (17, 18, 20). Following unaccustomed, eccentric or high intensity exercise, concentrations of CK in the blood rise, and may remain elevated for up to 7 days (4). In the current study CK increased from baseline levels to a peak at 24 h post exercise, with significantly lower values than SHAM being observed in the compression group from 24 to 48 h (Figure 2). It is possible that the compression garments attenuated muscular trauma, and so the appearance of CK throughout recovery (25).

Perceived muscle soreness was also significantly reduced in the compression garment group compared to the SHAM group (Figure 2). This is consistent with previous research (1, 11, 12, 21). Perception of muscle soreness increased following the muscle damaging protocol in both groups, suggesting participants were experiencing delayed onset muscle soreness (DOMS) following muscle damage, which can result in the voluntary and inherent loss of capacity to produce force within the muscle (28). Mechanical trauma to the tissue leading to structural damage and an inflammatory response is thought to be one of the main causes of the experience of DOMS (9), thus it is possible that a reduction in perceived soreness may be indicative of reduced tissue damage and resultant inflammation (1). As muscle damage can lead to an increase in osmotic pressure within the affected tissue, it has been speculated that the use of compression garments may attenuate the change in pressure gradient to reduce the sensation of pain (26).

In the current study, the use of compression garments had no significant effect on MVIC (Table 2). Similarly, compression garments had no significant effect on CMJ. Whilst this finding is in agreement with a number of studies that have assessed strength and power recovery following running based exercise (13, 14, 21) it is in marked contrast to a large body of data which suggests compression may aid muscular recovery following muscle damage (5, 20, 24, 25, 27). These findings may perhaps be explained by the relatively low levels of muscle damage observed following exercise. As such, the level of muscle damaged experienced by these players may have been too small for compression to have made a meaningful difference to functional recovery. For example, in the current study participant CK levels did not increase above 246 IU.L-1 in SHAM at 48h. Despite work by Jakeman et al. (24) recording similar peak values (276.5 IU.L-1), these CK concentrations are much lower than more typical values of 2194 IU.L-1 (16) and 1750 IU.L-1 (27)reported previously. Positive effects from compression garments on strength recovery have been reported after exercise eliciting circulating levels of CK over five times higher than those reported here (25, 27). It is possible that these low circulating levels of CK can be explained by considering participant training status and familiarity with the exercise employed. The rugby players studied in the current trial were well trained (competing at university level), which may have reduced their susceptibility to muscle damage (15). Furthermore, increased exposure to specific movements or exercises is also known to reduce subsequent levels of muscle damage (22). The rugby-specific exercise undertaken by the trained participants in this study may have therefore been insufficient to have impaired recovery to the extent where compression garments could have provided a meaningful benefit (5).

The fact that the compression tights used in the current study were fitted according to approximate (small, medium and large) sizes, may represent a major limitation. Variation in anthropometric characteristics and morphology within a population has been shown to result in large variations in applied garment pressures (19), while compressive pressures ranged from 5 - 13 mmHg at the thigh and 9 – 20 mmHg at the calf in the current study. These values are lower than many reported in previous research (2, 24), while current recommendations suggest that garments need to exert minimum pressures of 17.3 mmHg at the calf and 15.1 mmHg on the thigh, to increase venous return (30).

In conclusion, the use of lower limb compression garments following a rugby specific, muscle damaging protocol, resulted in a significant reduction in CK and PMS at 24 and 48 h post muscle damage. Nevertheless, there appeared to be no significant difference in CMJ and MVIC.

***PRACTICAL APPLICATIONS***

The use of lower limb compression garments following 48 h compression aids physiological measures of recovery in rugby union players, reducing CK and PMS. This may translate into a real-world practical benefit for athletes looking to maintain training intensity following muscle damage. While no benefits were shown on the recovery of physical performance, these findings were limited by the wide variation in the pressures applied by the garments, which may have resulted in insufficient pressures being applied.

***References***

1. Ali A, Caine, MP and Snow BG. Graduated compression stockings: Physiological and perceptual responses during and after exercise. *J Sports Sci* 25: 413-419, 2007.

2. Armstrong SA, Till ES, Maloney SR and Harris GA. *J Strength Cond Res* 2: 528 – 533, 2015.

3. Barnett A. Using recovery modalities between training sessions in elite athletes does it help? *J Sports Med* 36: 781-796, 2006.

4. Braid MF, Graham SM, Baker JS and Bickerstaff GF. Compression garments and exercise related muscle damage: implications for performance and recovery. *J Nutr Metab* 5: 235 – 241, 2012.

5. Brown F, Gissane C, Howatson G, van Someren K, Pedlar C and Hill J. Compression Garments and Recovery from Exercise: A Meta-Analysis. *Sports Med* 1-23, 2017.

6. Bryne C, Twist C and Eston R. Neuromuscular function after exercise-induced muscle damage. *J Sports Med* 34: 49 – 69, 2004.

7. Clarkson PM and Sayers SP. Etiology of exercise-induced muscle damage. *Can J Appl Physiol* 24: 234–248, 1999.

8. Cleak, MJ and Eston, RG. Muscle soreness, swelling, stiffness and strength loss after intense eccentric exercise*. Br J Sports Med* 26: 267–272, 1992.

9. Connolly DAJ, Sayers SP and McHugh MP. Treatment and prevention of delayed onset muscle soreness. *JSC* 17: 97-298, 2003.

10. Cunniffe B, Proctor W, Baker, JS and Davies B. An evaluation of the physiological demands of elite rugby union using global positioning system tracking software. *J Strength Cond Res* 23: 1195–1203, 2009.

11. Davies V, Thompson KG and Cooper SM. The effects of compression garments on recovery. *J Strength Cond Sci* 6: 1768 – 1794, 2006.

12. Duffield R, Cannon J and King M. The effects of compression garments on recovery of muscle performance following high intensity sprint and Plyometric exercise. *J Sci Med Sport* 13: 136-140, 2010.

13. Duffield R, Edge J, Merrells R, Hawke E, Barnes M, Simcock D, and Gill N. The effects of compression garments on intermittent exercise performance and recovery on consecutive days. *Int J Sports Physiol Perform* 4: 454-468, 2008.

14. Duffield R and Portus M. Comparison of three types of full body compression garments on throwing and repeat-sprint performance in cricket players. *Br J Sports Med,* 41: 409-414, 2007.

15. Falvo MS and Smith A. Repeated Bout Effect is Absent in Resistance Trained Men. An Electromyographic Analysis. *J Electromyogr Kinesiol* 19: e529-e535, 2010.

16. Gill ND, Beaven CM and Beaven CM. Effectiveness of post-match recovery strategies in rugby players. *Br J Sports Med* 40: 260-263, 2006.

17. Goodall S and Howatson G. The effects of cold water immersion on indices of muscle damage. *J Sports Med* 13: 121 127, 2008.

18. Green HJ. Mechanisms of muscle fatigue in intense exercise. *J Sports Sci* 15: 247-256, 1997.

19. Hill JA, Howatson G, van Someren KA, Davidson S and Pedlar CR. The variation in pressures exerted by commercially available compression garments. *Sports Eng*18: 115-121, 2015.

20. Hill JA, Howatson G, van Someren K, Leeder J and Pedlar CR. Compression garments and recovery from exercise-induced muscle damage: a meta-analysis. *Br J Sports Med* 48: 1340-1346, 2013.

21. Hill JA, Howatson G, van Someren K, Walshe I and Pedlar CR. Influence of compression on recovery after marathon running. *JSC* 8: 2228-2235, 2014.

22. Howatson GK, van Someren K and Hortobagyi T. Repeated bout effect after maximal eccentric exercise. *Int J Sports Med* 28: 557-563, 2007.

23. Ibegbuna V, Delis KT, Nicolaides AN and Aina O. Effect of elastic compression stockings on venous hemodynamics during walking. *J Vasc Surg* 37: 420–425, 2003.

24. Jakeman R, Bryne C, Roger G and Eston G. Efficacy of lower limb compression garments and their combined treatment of manual massage and lower limb compression on symptoms of exercise-induced muscle damage in women. *JSC* 21: 3157-3165, 2010.

25. Kraemer WJ, Flanagan SD, Comstock BA, Fragala, MS, Earp JE, Dunn LC, Ho JY, Thomas GA, Glenn SH, Penwell ZR, Powell MD, Wolf MR, Volek JS, Denegar CR, Craig R and Maresh CM. The effect of whole body compression garments on markers of recovery after a heavy resistance workout in men and women. *JSC* 3: 804 – 814, 2010.

26. Kraemer WJ, French DN and Spiering BA. Compression in the treatment of acute muscle injuries in sport. *Int J Sports Med* 5: 200-208, 2004.

27. Kraemer WJ, Bush JA, Wickham RB, Denegar CR, Gomez AL, Gotshalk LA, Duncan ND, Volek JS, Newton RU and Putukian M. Continuous compression as an effective therapeutic intervention in treating eccentric-exercise-induced muscle soreness. *J Sport Rehabil* 10: 11-23, 2001.

28. McHugh MP, Connolly DA, Eston RG and Gleim GW. Exercise induced muscle damage and potential mechanism for the repeated bout effect. *J Sports Med* 3: 157 – 170, 1999.

29. Scurr JH, Machin SJ, Bailey-King S, Mackie IJ, McDonald S and Smith PD. Frequency and prevention of symptomless deep-vein thrombosis in long-haul flights: A randomised trial. *Lancet* 357: 1485–1489, 2001.

30. Watanuki S and Murata H. The effect of wearing compression stockings on cardiovascular responses. *Ann Physiol Anthropol* 3: 121-127, 1994.

***Figure legends***

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