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# Compression garments and recovery from exercise-induced muscle damage: a meta-analysis

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## ABSTRACT

The purpose of the study was to determine the effects of compression garments on recovery following damaging exercise. A systematic review and meta-analysis was conducted using studies that evaluated the efficacy of compression garments on measures of delayed onset muscle soreness (DOMS), muscular strength, muscular power and creatine kinase (CK). Studies were extracted from a literature search of online databases. Data were extracted from 12 studies, where variables were measured at baseline and at 24 or 48 or 72 h postexercise. Analysis of pooled data indicated that the use of compression garments had a moderate effect in reducing the severity of DOMS (Hedges'  $g=0.403$ , 95% CI 0.236 to 0.569,  $p<0.001$ ), muscle strength (Hedges'  $g=0.462$ , 95% CI 0.221 to 0.703,  $p<0.001$ ), muscle power (Hedges'  $g=0.487$ , 95% CI 0.267 to 0.707,  $p<0.001$ ) and CK (Hedges'  $g=0.439$ , 95% CI 0.171 to 0.706,  $p<0.001$ ). These results indicate that compression garments are effective in enhancing recovery from muscle damage.

## INTRODUCTION

Training and athletic competition frequently result in exercise-induced muscle damage (EIMD). The degree of muscle damage depends on several factors including exercise type, duration, intensity and habituation to the exercise.<sup>1,2</sup> Exercise with an eccentric component results in a greater magnitude of negative symptoms associated with EIMD.<sup>3</sup> During an eccentric contraction, the muscle lengthens while under tension, resulting in mechanical damage to the sarcomeres; this mechanical damage leads to an inflammatory response, proposed to exacerbate the degree of damage.<sup>3</sup> EIMD is characterised by a number of symptoms including temporary reductions in muscle strength, decreased rate of force development, reduced range of motion, swelling, increased feelings of soreness and the appearance of intracellular proteins in the blood.<sup>2,4,5</sup> These symptoms can last for a number of days and may affect the capacity to train at the desired intensity in subsequent training sessions, thus having an impact on long-term training programmes and competition performance; as a result, methods to reduce the negative symptoms associated with EIMD are widely sought.

A number of modalities have been investigated in the search for a treatment that may reduce the effects of EIMD and/or accelerate recovery;<sup>6</sup> these include massage,<sup>7</sup> antioxidant supplementation,<sup>8</sup> cold water immersion<sup>9</sup> and recently the use of compression garments.<sup>10,11</sup> Compression garments are widely used to treat clinical pathologies such as

deep vein thrombosis and chronic-venous insufficiency.<sup>12,13</sup> The use of compression garments in sport is becoming increasingly popular due to claims that they can improve recovery from strenuous exercise<sup>14</sup> by creating an external pressure gradient, thus reducing the space available for swelling.<sup>10</sup> Other suggested benefits include enhanced blood flow that may aid the removal of waste products and muscle metabolites.<sup>10</sup>

Evidence for the efficacy of compression garments in alleviating symptoms associated with muscle damage is equivocal with studies both supporting<sup>15,16</sup> and refuting the use of garments.<sup>17</sup> MacRae *et al*<sup>11</sup> in their descriptive review on compression garments indicated that discrepancies in the findings might be due to the differences between studies in the populations, modality of exercise, degree of compression, type of compression garment and duration of treatment. Accordingly, in order to clarify the role of compression garments in recovery from EIMD, the aim of this investigation was to conduct a systematic review and meta-analysis on the efficacy of compression garments in recovery from damaging exercise.

## METHODS

### Literature search

A systematic review with meta-analysis was conducted using established guidelines.<sup>18</sup> An electronic search of the literature, ending in August 2012, was conducted using combinations of the following terms in three online databases (MEDLINE (Pubmed), SportDiscus and ISI Web of Knowledge): Compression garment, compression stocking, exercise, EIMD, performance, recovery, sport. The reference lists of all obtained articles were examined in order to identify any further studies.

### Outcome variables

The literature was examined for the effects of compression garments on recovery from damaging exercise using the following outcome variables which reflect the most commonly assessed indices in the EIMD literature: muscular power, muscular strength, muscle soreness and creatine kinase (CK). Measurements of muscular power included any activity that measured the explosive power of the muscle; examples include a counter-movement jump and a 5 m sprint. Muscular strength included measurements of isometric/isokinetic/isotonic muscle contraction. Measurements of delayed onset muscle soreness (DOMS) were obtained through the use of visual analogue scales or Likert scales and, finally, measurements of CK obtained from capillary or venous sampling.

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### Inclusion and exclusion criteria

Studies were included on the basis of the following criteria: (1) participants were randomised into a compression garment or control group; (2) If they measured at least one of the outcome variables and assessed at baseline and again at 24 and/or 48 and/or 72 h after the exercise bout; (3) the study population could be male or female participants from any training background; (4) if the compression garment was worn after, or during and after the damaging exercise. Studies were excluded if: (1) the compression garment was not applied within 2 h of exercise completion; (2) the experimental group received multiple treatments or the control group undertook any practice which could be perceived to improve recovery; (3) there was insufficient data.

### Extraction of data

Mean, SD and sample size data were extracted from all included studies. In some cases, the mean and SD data were extrapolated from the figures. Where data were reported as the mean and SE, data were converted to SE values. Risk of bias was calculated in accordance with the Cochrane Collaboration Guidelines<sup>19</sup> (figure 1).

### Statistical analysis

All analyses were conducted using comprehensive meta-analysis software (V2.2.057; Biostat Inc, Englewood, New Jersey, USA). All data were analysed using a fixed-effect model. Hedges' *g* with 95% CI was used to indicate the standardised mean differences. Effect sizes were set at <0.40=small, 0.40–0.70=moderate and >0.70=large.<sup>20</sup> Systematic differences (heterogeneity) were assessed using an  $I^2$  statistic, which indicates the percentage of variability across studies due to heterogeneity.<sup>20</sup> A significance level of  $p \leq 0.05$  was applied.

## RESULTS

A total of 5292 records were identified through database searches and a further seven studies were identified through reference list searches. Of the total 5299 records screened, 5250 were not relevant to this analysis and were excluded, leaving 49 studies to be assessed for eligibility. Of the 49 potentially relevant studies, 37 were excluded due to: missing data; different outcome variables from the inclusion criteria reported; outcome variables not measured in accordance with the inclusion criteria time points; application timings of the compression garment were not in accordance with the inclusion criteria (see figure 2). Twelve studies that met the inclusion criteria had data extracted for inclusion in the meta-analysis (see table 1). The training status of the participants in the included studies ranged from untrained to elite. The total number of participants in the data set was 205 (n=136 men and n=69 women) with a mean and SD age of 22.3 (2.3) years. Risk of bias is indicated in figure 1. The outcome of the assessment revealed that sequence generation and allocation concealment were largely unclear and that none of the studies were able to blind participants from the treatment.

A total of 28 data points were extracted from original research papers and included in the final analysis. The use of compression garments had a moderate benefit in reducing the experience of DOMS (Hedges' *g*=0.403, 95% CI 0.236 to 0.569,  $p < 0.001$ ; figure 3). The  $I^2$  statistic indicated a minimal heterogeneity (0.001%).<sup>20</sup>

The use of compression garments appeared to have a moderate effect on recovery of muscle strength postexercise (Hedges' *g*=0.462, 95% CI 0.221 to 0.703,  $p < 0.001$ ). Analysis was

conducted using a sample of 15 extracted data points (figure 4). An  $I^2$  statistic of 4.8% revealed minor heterogeneity.

Figure 5 demonstrates that the use of compression garments has a moderate effect on the recovery of muscle power following exercise (Hedges' *g*=0.487, 95% CI 0.267 to 0.707,  $p < 0.001$ ). Seventeen extracted data points were included in the analysis. An  $I^2$  value of 0.001% suggests minor heterogeneity.

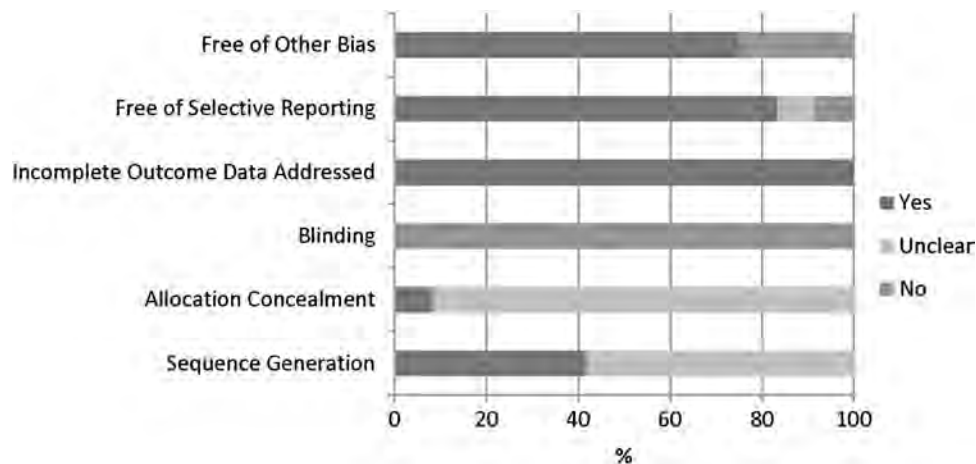
Analysis of 18 extracted data points (figure 6) revealed that the use of compression garments had a moderate effect in reducing concentrations of CK postexercise (Hedges' *g*=0.439, 95% CI 0.171 to 0.706,  $p < 0.001$ ). An  $I^2$  value of 37.4% indicates moderate heterogeneity<sup>20</sup>

## DISCUSSION

There is a growing body of literature examining the use of compression garments in performance and recovery; however, the effectiveness of these garments is still in question. The wide variation in methodological design, combined with the differences in timing and duration of application, exercise modality and training status of the population investigated, has perhaps contributed to the apparently inconsistent findings. This study used a meta-analysis approach to explore whether the use of compression garments, as a recovery modality, are effective. The results indicate that when compression garments are worn after, or during and after, intense exercise, participants experience a moderate reduction in severity of DOMS, reduced decrements in strength and power and a reduced concentration of CK in the serum.

The results suggest that using a compression garment alleviates the perception of DOMS. The total Hedges' *g* of 0.40 (figure 3) indicates that, with the use of compression, 66% of the population<sup>21</sup> is likely to experience reduced DOMS. The underlying mechanism explaining the cause of DOMS currently remains unclear.<sup>22–23</sup> Several theories have been proposed, with some authors suggesting that DOMS arises as a result of disruption to the muscle fibre and surrounding connective tissue,<sup>24</sup> others suggesting that it is associated with the inflammatory response<sup>25</sup> and yet others suggesting that it is a combination of both.<sup>1</sup> The inflammatory response, which follows tissue damage, creates an increase in tissue osmotic pressure, which sensitises nociceptors, resulting in sensations of pain and soreness.<sup>26</sup> Although somewhat speculative, it is thought that applying compression generates an external pressure gradient that attenuates changes in osmotic pressure and reduces the space available for swelling and haematoma to occur.<sup>26</sup> A reduction in osmotic pressure, occurring due to a decrease in exudates, may lessen the degree of chemotaxis, thus attenuating the inflammatory response and experience of pain;<sup>26</sup> however, this remains to be empirically demonstrated. Nonetheless, a reduction in DOMS is beneficial for athletes and may improve an individual's readiness to participate in physical activity.<sup>27</sup>

Principally, compression garments are worn during recovery in order to improve subsequent performance.<sup>11</sup> The current review demonstrates that the performance measures of strength and power recover at a faster rate with the use of a compression garment. The overall Hedges' *g* of 0.49 and 0.44 for strength and power (figures 4 and 5) indicate that 69% and 66%, respectively, of the population<sup>21</sup> will experience accelerated recovery of strength and power when using a compression garment. Reductions in muscular function have been attributed to muscle soreness,<sup>28</sup> ultrastructural damage<sup>29</sup> and reduced voluntary muscle activation.<sup>30</sup> It is very likely that ultrastructural damage is not the only factor that causes a temporary decrease in muscle function. Previous research has indicated that ultrastructural



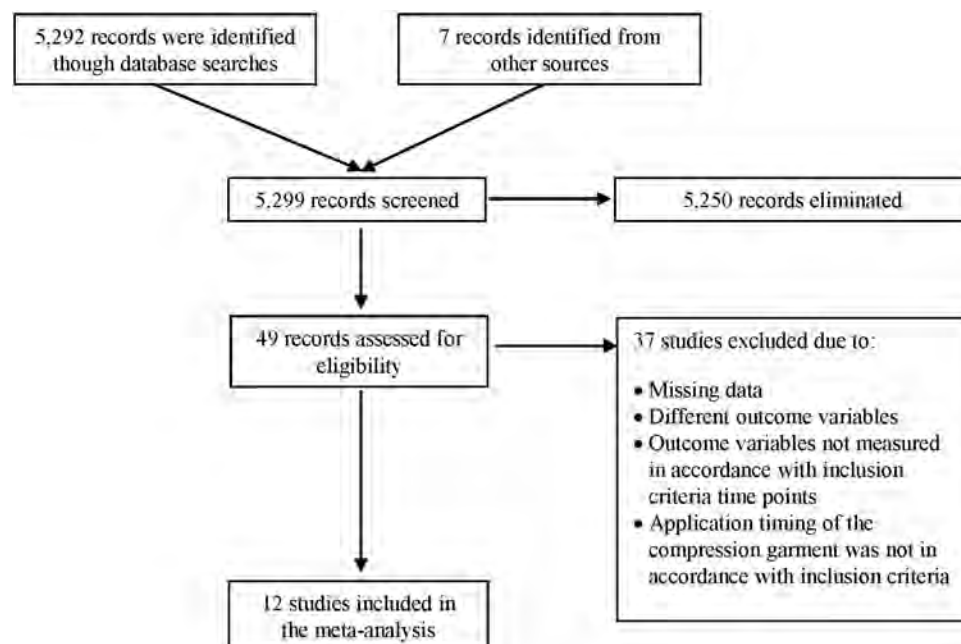
**Figure 1** Analysis of the risk of bias in accordance with the Cochrane Collaboration.<sup>19</sup>

damage does not always occur following eccentric exercise that leads to DOMS.<sup>31</sup> Therefore, it seems reasonable that reduced voluntary muscle activation also contributed to a reduction in muscular strength, which is consistent with previous research.<sup>30</sup> Considering this, the recovery of muscle function with the use of compression garments either (1) reduces the inflammatory response, thus attenuating further ultrastructural damage occurring 48–72 h postexercise or (2) is able to accelerate restoration of central factors that result in reduced voluntary activation. Furthermore, the use of a compression garment may provide dynamic immobilisation, which reduces muscle oscillation and, in turn, enhances the neural input during the recovery process.<sup>28</sup>

CK has been used extensively as a marker of muscle damage.<sup>3 10 32</sup> This study indicated that the use of compression garments is able to reduce concentrations of CK. A Hedges'  $g$  value of 0.44 (figure 6) indicates that 66% of the population<sup>21</sup> will experience a reduced CK in blood. Reductions in CK concentrations observed with the use of compression garments have

been attributed to an attenuation in the release of CK into the bloodstream, improved clearance of metabolites<sup>26</sup> and enhanced repair of the muscle.<sup>33</sup> Compression garments may improve circulation, probably via an enhanced-muscle pump function; however, the exact mechanism remains speculative.<sup>33</sup> Nevertheless, an improved venous return may facilitate the clearance of metabolites,<sup>34</sup> which may explain why reduced levels of CK are evident following the application of compression.

A moderate risk of heterogeneity was revealed for CK across the studies in this analysis; this is perhaps related to differences in training status of the participants in each study and the type of exercise modality used; for example, Montgomery *et al*<sup>35</sup> investigated recovery following a basketball tournament using well-trained participants. In contrast to this, Kraemer *et al*<sup>14 28</sup> examined recovery following two sets of 50 arm curls using non-strength-trained men and women. The CK response at 72 h postexercise in Kraemer *et al*<sup>14</sup> appears inexplicably to be much larger in magnitude in comparison with all other studies included in the analysis, potentially skewing the overall CK findings

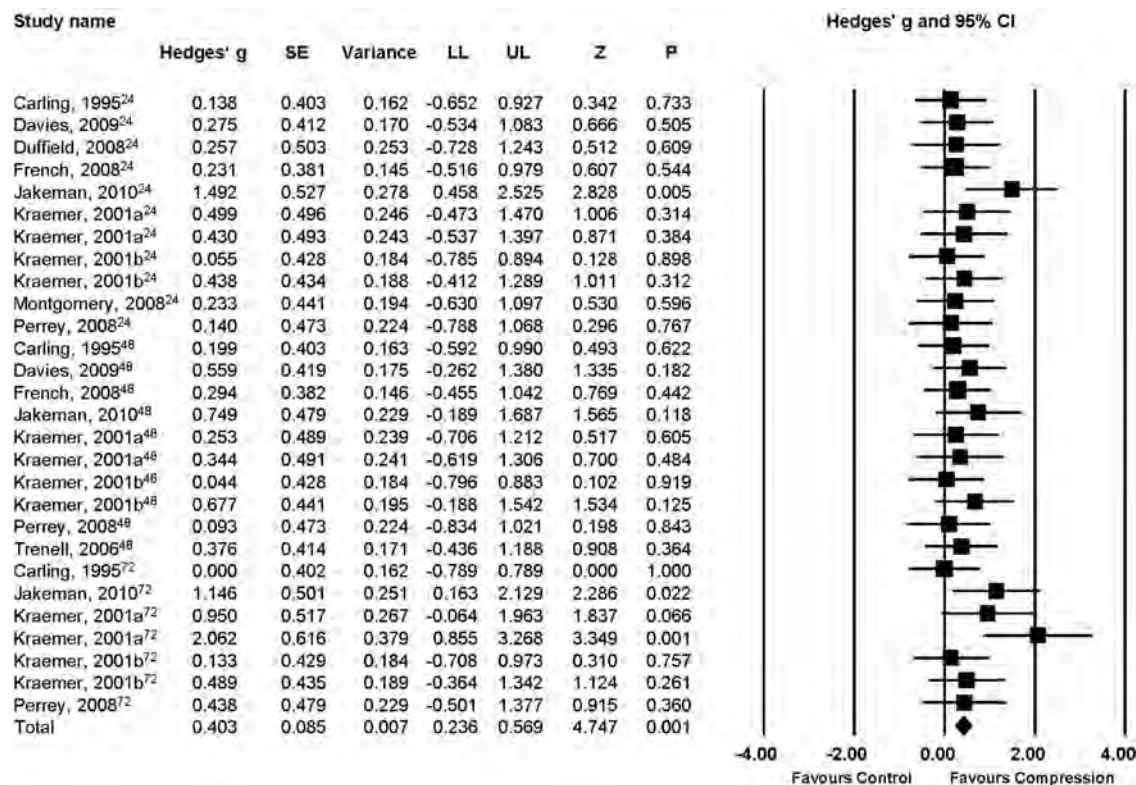


**Figure 2** Process of study selection from initial identification to inclusion.

**Table 1** Summary of the literature included in the meta-analysis

Author(s)	Participant cohort (training status, gender, number)	Exercise intervention	Type of compression garment	Timing and duration of application	Outcome variables and measurement times (h)
Carling <i>et al</i> <sup>17</sup>	23 college students n=7 males, n=16 females	70 eccentric contractions of non-dominant elbow flexors	Compression sleeve extending from deltoid insertion to wrist (Brecon Inc, Talladega, AL) 17 mm Hg	72 h postintervention	DOMS (24, 48, 72) Peak concentric torque (24, 48, 72)
Davies <i>et al</i> <sup>10</sup>	Female University team netball players n=7 Male University team basketball players n=4	5×20 drop jumps	Compression tights (Linebreak) 15 mm Hg	48 h postintervention	DOMS (24, 48) CMJ (48) 5 m sprint (48) 10 m sprint (48)
Duffield <i>et al</i> <sup>28</sup>	Male club and regional standard rugby players n=11	10 m x 20 m sprints and 100 SSC bounds	Lower body (Bioslyx, Salzenger, Australia)	During and 24 h postintervention	Peak quadriceps extension force (24) Peak flexion of hamstrings (24) Knee extensor peak twitch force (24) CK (24)
Duffield <i>et al</i> <sup>27</sup>	Club standard rugby players n=14	Simulated team game	Lower body (Skins, Sydney, Australia)	During and 15 h postintervention	DOMS (24) Peak power (24) CK (24)
Duffield and Portus <sup>36</sup>	Male club level cricket players n=10	30-min intermittent, repeated sprint test	Whole body (3 different brands; Skins, Sydney, Australia; Under Armour, Baltimore, Maryland, USA; Adidas, Herzogenaurach, Germany)	During and 24 h postintervention	CK (24)
French <i>et al</i> <sup>22</sup>	Healthy young men n=26	Standardised whole body resistance exercise protocol	Lower body, ankle to waist (Skins, Campbeltown, Australia) 12–10 mm Hg	12 h post	DOMS (24, 48) CK (24, 48)
Jakeman <i>et al</i> <sup>16</sup>	Physically active females n=17	10×10 polymeric drop jumps	Lower limb (Skins, Sydney, Australia)	12 h post	DOMS (24, 48, 72) Isokinetic muscle strength (24, 48, 72) Squat jump (24, 48, 72) CMJ (24, 48, 72) CK (24, 48, 72)
Kraemer <i>et al</i> <sup>14</sup>	Healthy non-strength trained men n=15	2×50 arm curls	Compression sleeve fitted from axillary line to forearm 10 mm Hg	72 h post	DOMS (movement) (24, 48, 72) DOMS (global) (24, 48, 72) Peak torque (24, 48, 72) Peak elbow flexor power (24, 48, 72) CK (24, 48, 72)
Kraemer <i>et al</i> <sup>28</sup>	Non-strength trained women n=29	2×50 arm curls	Compression Sleeve fitted from axillary line to forearm 10 mm Hg	120 h post	DOMS (movement) (24, 48, 72) DOMS (global) (24, 48, 72) Peak torque (24, 48, 72) Peak elbow flexor power (24, 48, 72) CK (24, 48, 72)
Montgomery <i>et al</i> <sup>35</sup>	Well-trained male basketball players n=29	Basketball tournament	Lower body (Linebreak, Sydney, Australia) 18 mm Hg	18 h post	DOMS (24) Jump Height (24)
Perrey <i>et al</i> <sup>39</sup>	Healthy physically active men n=8	30-min, backwards-downhill walking	Calf length (SportivTM, France) Single leg	5 h/day at 2, 24 and 48 h post	DOMS (24, 48, 72)
Trenell <i>et al</i> <sup>15</sup>	Recreational male athletes n=11	30-min downhill walking	Lower Limb (Skins, Sydney, Australia) Single Leg	48 h post	DOMS (48)

CMJ, counter-movement jump; CK, creatine kinase; DOMS, delayed-onset muscle soreness.

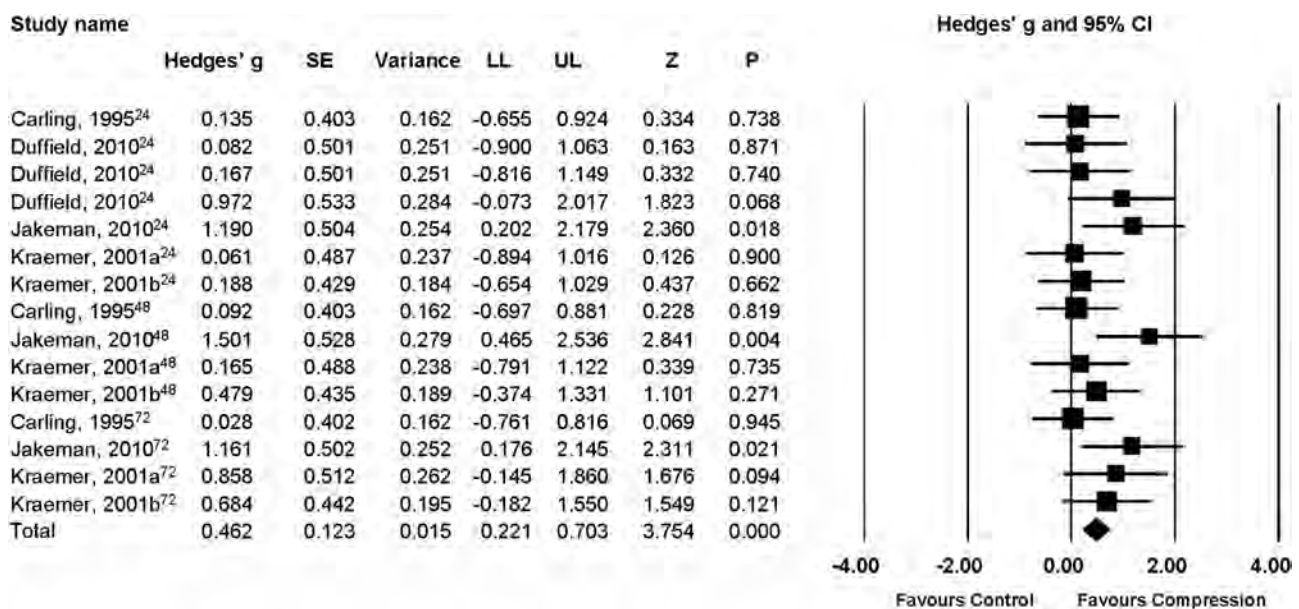


**Figure 3** Forest plot demonstrating a comparison between the use of a compression garment and a control for measures of delayed-onset muscle soreness. The superscripted 24, 48 and 72 refer to the postexercise measurement times. Squared indicate the Hedges' g for each study and the lines represent 95% CIs. The size of the square represents the weight of the study. The diamond indicates the overall Hedges' g, with its width representing the 95% CIs. LL and UL represent the lower limit and upper limit of 95% CIs, respectively.

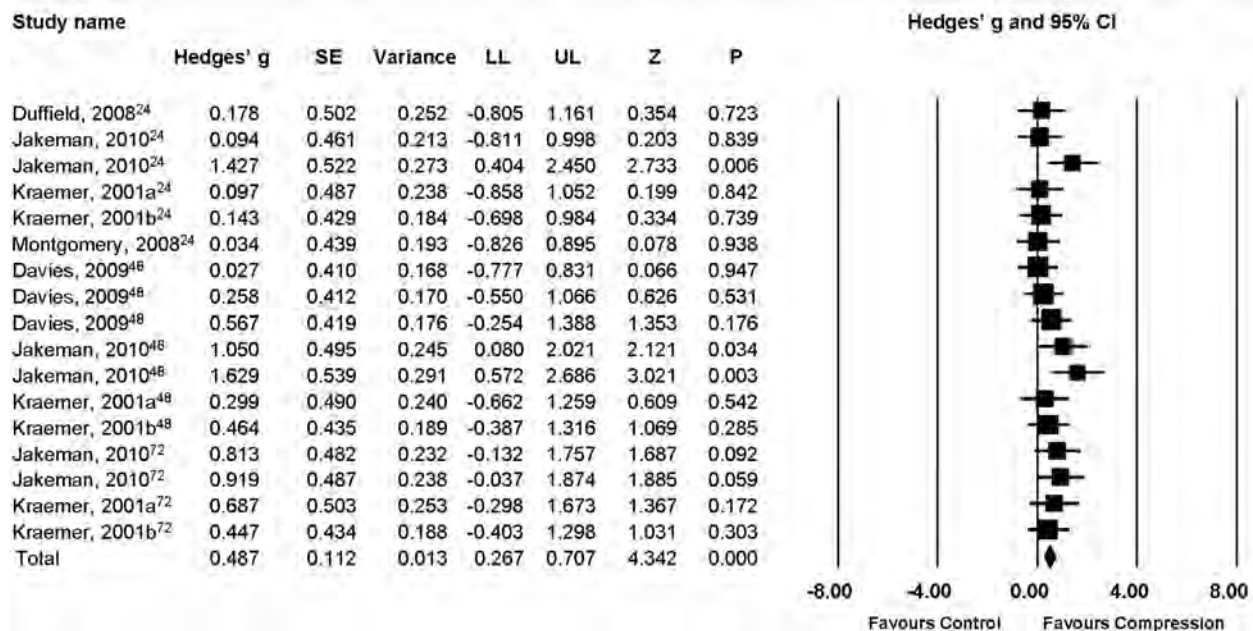
and contributing to the increased risk of heterogeneity observed. The CK response appears to be inconsistent following the application of compression, with some studies indicating a reduction in CK<sup>14 28 36</sup> and others indicating no change.<sup>10 32</sup> It is also important to consider that serum CK is a reflection of both diffusion and

clearance from the circulatory system; as a result, changes in CK concentration should be interpreted with some caution.<sup>32</sup>

The role of compression garments as a recovery modality is thought to be related to enhanced-tissue repair.<sup>15 33</sup> The results from the meta-analysis provide evidence that the use of



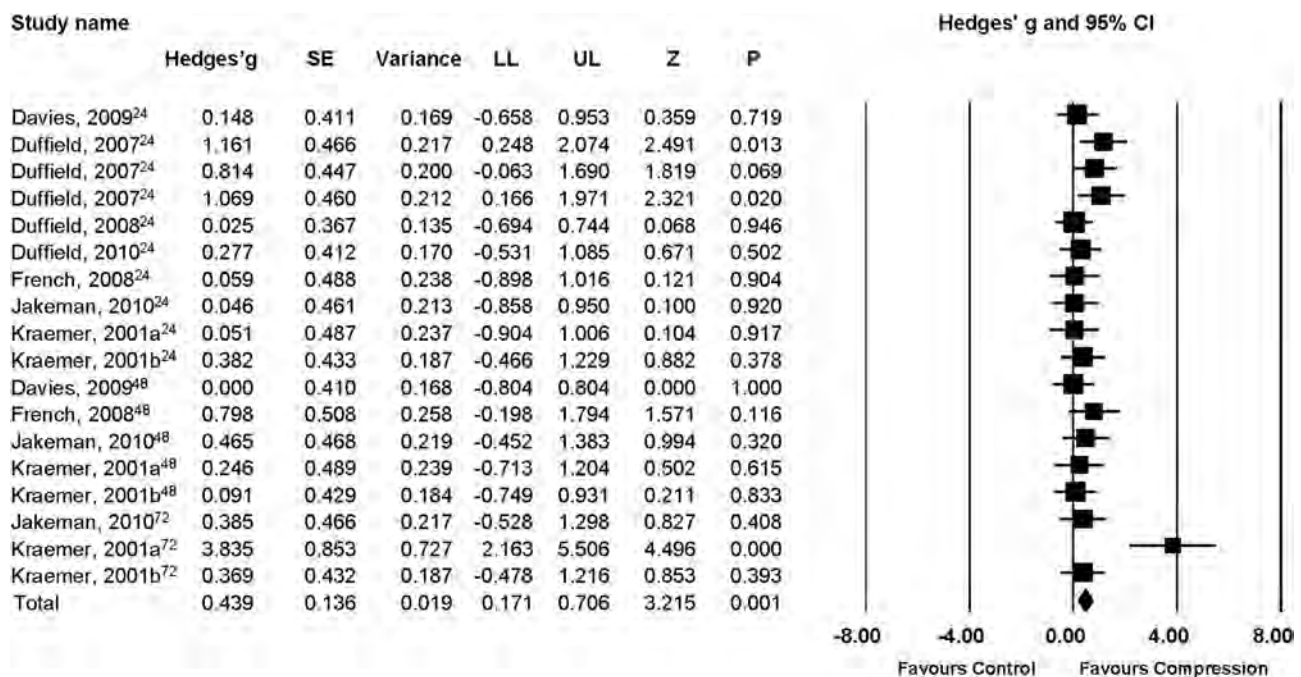
**Figure 4** Forest plot demonstrating a comparison between the use of a compression garment and a control for measures of muscular strength. The superscripted 24, 48 and 72 refer to the postexercise measurement times. Squared indicate the Hedges' g for each study and the lines represent 95% CIs. The size of the square represents the weight of the study. The diamond indicates the overall Hedges' g, with its width representing the 95% CIs. LL and UL represent the lower limit and upper limit of 95% CIs, respectively.



**Figure 5** Forest plot demonstrating a comparison between the use of a compression garment and a control for measures of muscle power. The superscripted 24, 48 and 72 refer to the postexercise measurement times. Squared indicate the Hedges' g for each study and the lines represent 95% CIs. The size of the square represents the weight of the study. The diamond indicates the overall Hedges' g, with its width representing the 95% CIs. LL and UL represent the lower limit and upper limit of 95% CIs, respectively.

compression may reduce the recovery time frame; however, any meta-analysis is limited by the data available and there are several limitations in the literature used in this analysis; (1) Many of the studies included contain small sample sizes, which results in reduced statistical power; (2) None of the included studies blinded their patients to the treatment; as such, the

placebo effect cannot be eliminated; (3) Many of the studies do not describe the method used to randomise subjects; nor do they mention allocation concealment and (4) the garments used within each of the studies also vary widely and include upper body and lower body garments from a range of manufacturers, which are likely to exert different degrees of pressure.



**Figure 6** Forest plot demonstrating a comparison between the use of a compression garment and a control for measures of CK. The superscripted 24, 48 and 72 refer to the postexercise measurement times. Squared indicate the Hedges' g for each study and the lines represent 95% CIs. The size of the square represents the weight of the study. The diamond indicates the overall Hedges' g, with its width representing the 95% CIs. LL and UL represent the lower limit and upper limit of 95% CIs, respectively.

The majority of published studies do not measure the degree of pressure exerted by the garments and simply report the estimated levels indicated by the manufacturer. A potential problem with this is that the garments are usually fitted based on the individual's height and weight. Owing to the differences in body shape and variations in tissue structure, there may be large ranges in the pressure exerted locally by a garment in one size classification.<sup>11</sup> These differences may explain some of the variation in findings within the literature and future research should account for this by directly measuring the degree of compression achieved. Finally, trained participants are likely to experience fewer negative symptoms following intense exercise when compared with their non-trained counterparts, due to the level of habituation to exercise and the repeated bout phenomenon.<sup>37</sup> However, there is a lack of evidence to support this theory in the context of compression garments.

## CONCLUSION

A number of events are involved in the damage-inflammation-recovery process and they are initiated very quickly following the damaging bout; therefore, rapid deployment of a treatment strategy is important.<sup>26</sup> This is the first systematic review with meta-analysis to examine the efficacy of compression garments in recovery from damaging exercise. These data provide new information that the use of compression garments promotes a more rapid recovery of muscle function, muscle soreness and systemic CK activity when compared with a control group. Further research is needed that investigates the relationship between garment, fit, the pressure exerted by the garment, the training status of the athlete and the effect this has on markers of recovery. This may address some of the inconsistent findings within the current literature. Although the physiological mechanisms remain to be fully understood, this review highlights that the use of a compression garment appears to facilitate enhanced recovery of muscle function and reduce muscle soreness.

## SUMMARY OF FINDINGS

The use of compression garments appears to reduce the severity of DOMS, accelerate the recovery of muscle function and attenuate the concentration of CK following strenuous exercise. These findings indicate that wearing a compression garment may improve recovery following intense training and competition; this has implications for both elite athletes and recreational populations.

**Contributors** JH participated in protocol design, data extraction, data analyses and manuscript preparation. GH, KVS, JL and CP participated in protocol design, data analyses and manuscript preparation. All authors have read and approved the final manuscript.

**Competing interests** None.

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## REFERENCES

- Connolly DAI, Sayers SP, McHugh MP. Treatment and prevention of delayed onset muscle soreness. *J Strength Cond Res* 2003;17:197–208.
- Tee JC, Bosch AN, Lambert MI. Metabolic consequences of exercise-induced muscle damage. *Sports Med* 2007;37:827–36.
- Clarkson PM, Sayers SP. Aetiology of exercise-induced muscle damage. *J Appl Physiol* 1999;24:234–48.
- Cleak MJ, Eston RG. Muscle soreness, swelling, stiffness and strength loss after intense eccentric exercise. *Br J Sport Med* 1992;26:267–71.
- Byrne C, Twist C, Eston R. Neuromuscular function after exercise induced muscle damage. Theoretical and applied implications. *Sports Med* 2004;34:49–69.
- Howatson G, Van Someren K. The prevention and treatment of exercise induced muscle damage. *Sports Med* 2008;38:483–503.
- Hilbert JE, Sforzo GA, Swensen T. The effects of massage on delayed onset muscle soreness. *Br J Sport Med* 2003;37:72–5.
- Mastaloudis A, Traber MG, Carstensen K, et al. Antioxidants did not prevent muscle damage in response to an ultramarathon run. *Med Sci Sports Exerc* 2006;38:72–80.
- Goodall S, Howatson G. The effects of multiple cold water immersions on indices of muscle damage. *J Sports Sci Med* 2008;7:235–41.
- Davies V, Thompson KG, Cooper SM. The effects of compression garments on recovery. *J Strength Cond Res* 2009;23:1786–94.
- MacRae BA, Cotter JD, Laing RM. Compression garments and exercise: garment considerations, physiology and performance. *Sports Med* 2011;41:815–43.
- Scurr JH, Machin SJ, Bailey-King S. Frequency and prevention of symptomless deep-vein thrombosis in long-haul flights: a randomised trial. *Lancet* 2001;357:1485–9.
- Ibegbuna V, Delis KT, Nicolaidis AN, et al. Effect of elastic compression stockings on venous hemodynamics during walking. *J Vasc Surg* 2003;37:420–5.
- Kraemer WJ, Bush JA, Wickham RB, et al. Influence of compression therapy on symptoms following soft tissue injury from maximal eccentric exercise. *J Orthop Sport Phys* 2001;31:282–90.
- Trenell MI, Rooney KB, Sue CM, et al. Compression garments and recovery from eccentric exercise: a P-MRS study. *J Sports Sci Med* 2006;5:106–14.
- Jakeman JR, Byrne C, Eston RG. Efficacy of lower limb compression and combined treatment of manual massage and lower limb compression on symptoms of exercise induced muscle damage in women. *J Strength Cond Res* 2010;24:3157–65.
- Carling J, Francis K, Lorish C. The effects of continuous external compression on delayed-onset muscle soreness (DOMS). *Int J Rehabil Health* 1995;1:223–35.
- Liberati A, Altman DG, Tetzlaff J, et al. The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions: explanation and elaboration. *Ann Intern Med* 2009;151:W65–94.
- Higgins JPT, Altman DG. Assessing the risk of bias in included studies. In: Higgins JPT, Green S, eds. *Cochrane handbook for systematic reviews of interventions*. Chichester: Wiley Blackwell, 2008:187–242.
- Higgins JPT, Green S. *Cochrane handbook for systematic reviews of interventions*. Chichester: Wiley Blackwell, 2008.
- Coe R. *It's the effect size, stupid. What effect size is and why it is important*. Exeter, UK: British Educational Research Association, 2002.
- Cheung K, Hume PA, Maxwell L. Delayed onset muscle soreness: treatment strategies and performance factors. *Sports Med* 2003;33:145–64.
- MacIntyre DL, Reid WD, McKenzie DC. Delayed muscle soreness. The inflammatory response to muscle injury and its clinical implications. *Sports Med* 1995;20:24–40.
- Stauber WT, Clarkson PM, Fritz VK, et al. Extracellular matrix disruption and pain after eccentric muscle action. *J Appl Physiol* 1990;69:868–94.
- Smith L. Acute inflammation: the underlying mechanism in delayed onset muscle soreness? *Med Sci Sports Exerc* 1991;23:542–51.
- Kraemer WJ, French DN, Spiering BA. Compression in the treatment of acute muscle injuries in sport. *Int Sport Med J* 2004;5:200–8.
- Duffield R, Edge J, Merrells R, et al. The effects of compression garments on intermittent exercise performance and recovery on consecutive days. *Int J Sports Physiol Perform* 2008;3:454–68.
- Kramer WJ, Bush JA, Wickham RB, et al. Continuous compression as an effective therapeutic intervention in treating eccentric-exercise induced muscle soreness. *J Sport Rehabil* 2001;10:11–23.
- Clarkson PM, Nosaka K, Braun B. Muscle function after exercise-induced muscle damage and rapid adaptation. *Med Sci Sports Exerc* 1992;24:512–20.
- Prasartwuth O, Taylor JL, Gandevia SC. Maximal force, voluntary activation and muscle soreness after eccentric damage to human elbow flexor muscles. *J Physiol* 2005;567:337–48.
- Yu J, Malm C, Thornell L. Eccentric contractions leading to DOMS do not cause loss of desmin nor fibre necrosis in human muscle. *Histochem Cell Biol* 2002;118:29–34.
- French DN, Thompson KG, Garland SW, et al. The effects of contrast bathing and compression therapy of muscular performance. *Med Sci Sports Exerc* 2008;40:1297–306.
- Kraemer WJ, Flanagan SD, Comstock BA, et al. Effects of a whole body compression garment on markers of recovery after a heavy resistance workout in men and women. *J Strength Cond Res* 2010;24:804–14.
- Ali A, Caine MP, Snow BG. Graduated compression stockings: physiological and perceptual responses during and after exercise. *J Sport Sci* 2007;25:413–19.
- Montgomery PG, Pyne DB, Cox AJ. The effect of recovery strategies on physical performance and cumulative fatigue in competitive basketball. *J Sport Sci* 2008;26:1135–45.
- Duffield R, Portus M. Comparison of three types of full body compression garments on throwing and repeat-sprint performance in cricket players. *Brit J Sport Med* 2007;41:409–14.
- Barnett A. (2006). Using recovery modalities between training sessions in elite athletes. Does it help? *Sports Med* 2006;36:781–96.
- Duffield R, Cannon J, King M. The effects of compression garments on recovery of muscle performance following high-intensity sprint and plyometric exercise. *J Sci Med Sport* 2010;13:136–40.
- Perrey S, Bringard A, Racinais S, et al. Graduated compression stockings and delayed onset muscle soreness. In: Estivalet M, Brisson P, eds. *The engineering of sport*. Paris: Springer, 2008:547–54.



## Compression garments and recovery from exercise-induced muscle damage: a meta-analysis

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