Original Article

Evaluating the acute effect of compression socks for recovery between exercise bouts

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ABSTRACT

The current study aimed to investigate the acute application of compression socks for recovery after a strenuous bout of lower-body exercise. 58 active young adults (29 females, 29 males) performed ankle range of motion, calf circumference, isometric strength, calf endurance and perceived muscle soreness measures at baseline, and up to 48 hours following a strenuous bout of lower-body exercise. During the 30-minute recovery period, participants were randomly assigned an experimental leg (compression sock - COMP) and a control leg (passive recovery - CON). No significant group x time interactions were recorded ($p > .05$) and effect sizes were mostly trivial, except for a small decrease in perceived muscle soreness in COMP compared to CON immediately post-recovery (d = -0.29). For both groups, calf circumference increased, and calf endurance was reduced following exercise ($p < .001$), while perceived muscle soreness increased significantly over the follow-up period compared to baseline ($p < .001$). The application of compression socks for 30-minutes following intense calf exercise had little effect on physical measures but may result in a *small* decrease in perceived muscle soreness immediately following their use for recovery. These garments could be a viable recovery option for athletes with a short timeframe in between training bouts.

Keywords: Sport medicine, Sports performance, Recovery intervention, Compression garments, DOMS.

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INTRODUCTION

To facilitate optimal athletic performance adaptation and enhancement, the balance between training stimulus and training recovery must be optimised for each individual athlete (Kellmann & Beckmann, 2018). During recovery periods, athletes may choose to implement various recovery interventions designed to alleviate some of the symptoms of training fatigue, such as increased musculoskeletal pain and discomfort, reduced range of motion, and decreased muscular force production (Kellmann et al., 2018). While there are numerous recovery interventions available, the selection and use of such tools and protocols should be guided by the training stress applied and the specific needs of the individual, as well as season phase (Kellmann et al., 2018). For example, during a pre-season phase athletes may forgo or limit recovery interventions to promote physical adaptation to maximal training stress (Kellmann et al., 2018). In contrast, athletes maintaining a phase of high-volume training or competition with multiple sessions per day may prioritise the use of short-term recovery interventions, such as foam rolling, cold water therapy or massage, to reduce perceived muscle soreness and perceived fatigue, and improve the quality of subsequent training (Barnett, 2006). However, in many cases, the efficacy of these post-exercise recovery modalities and whether they are actually advantageous for use by athletes between sessions is not well elucidated (Barnett, 2006).

One example of a practical short-term recovery intervention is the use of compression garments (CGs), which were originally developed to treat conditions such as deep vein thrombosis and pulmonary oedemas (Hirai, 1999). In clinical settings, these garments are used to promote blood flow from superficial veins into deep veins and thereby prevent cutaneous venous statis (Galanaud et al., 2013). More recently, compression garments have become well-established as a common sports performance and recovery tool, and can be worn in upper-limb, lower-limb, or full-body styles (Leabeater et al., 2022). While their effectiveness as a performance tool during exercise is limited, using compression garments for recovery tends to have positive physiological benefits which may improve subsequent performance (Leabeater et al., 2022). For example, significant reductions in calf girth and cross-sectional area have been reported with the use of compression socks following strenuous team sport training (Broatch et al., 2019) and running time trials (Brophy-Williams et al., 2017), which may reflect reduced limb oedema and reduced muscle damage from prior exercise (Brophy-Williams et al., 2017). Meanwhile, Shimokochi et al. (2017) demonstrated improved recuperation of isometric knee extension strength when lower-body CGs were worn following high-volume strength training. Importantly, CGs have been shown to consistently improve perceptual measures such as perceived recovery and perceived muscle soreness when worn after exercise (Weakley et al., 2021), which contributes to their popularity amongst athletes and sports teams (Driller & Brophy-Williams, 2016). As recovery is an integrated state of both physiological and psychological inputs, the potential benefit of recovery interventions such as compression garments on perceptual recovery should not be overlooked.

While compression garments have been seen to have a positive influence on measures of limb circumference, isometric strength and sports performance after 8+ hours of wear (Broatch et al., 2019; Brophy-Williams et al., 2017; Shimokochi et al., 2017), this time period may not be practical for athletes seeking a short-term recovery intervention between training sessions. Indeed, previous research has identified that athletes most commonly use compression garments within four hours following exercise (Driller & Brophy-Williams, 2016). Only a small number of studies have investigated much shorter periods of compression garment wear, with practical improvements in five-kilometre running and five-minute maximal cycling performance demonstrated with recovery periods of less than 80 minutes using compression socks (Brophy-Williams et al., 2017; Chatard et al., 2004; Lee et al., 2021). Additionally, significant reductions in blood lactate after moderate-intensity upper body resistance training have been demonstrated with the use of compressive arm sleeves for only 20 minutes (da Silva Chiappa, 2021). In comparison, the effect of short-term compression wear on measures of lower-limb function and performance after strenuous exercise is not well elucidated. As such, the present study aimed to evaluate the effect of a 30-minute application of compression socks on physical and perceptual recovery following strenuous calf exercise.

MATERIAL AND METHODS

Participants

58 active young adults between 18–30 years of age volunteered to participate in the current study (29 females, height 165.7 ± 6.6 cm, body mass 65.4 ± 7.3 kg; 29 males, height 179.4 ± 5.9 cm, body mass 82.4 ± 10.3 kg). Participants were recruited through a university sport science under-graduate program. All participants were participating in regular physical exercise sessions (~3 times per week) and were free from lower-limb injuries (hip, knee or ankle) that may have affected their ability to perform the physical performance tests or exercise protocol. Written informed consent was obtained from each participant, and ethical approval was obtained from the Human Research Ethics Committee of the institution (HEC21274).

Measures

Calf circumference

To assess any lower-limb swelling associated with the exercise recovery intervention, the circumference of each leg at the calf was recorded at baseline and following recovery using a non-stretch anthropometric measuring tape (Lufkin Executive Thinline, TX, USA). The landmark used was at the widest girth of the calf muscle. The measurement site was marked using a permanent marker to ensure high levels of test-retest reliability across timepoints (Figure 1). This method of assessing calf circumference has been shown to have high reliability (SEM = 0.5-0.6cm; ICC = 0.97) (Carmont et al., 2013) and has been shown to correlate with muscle volume (R^2 = .42) (Rosso et al., 2013).

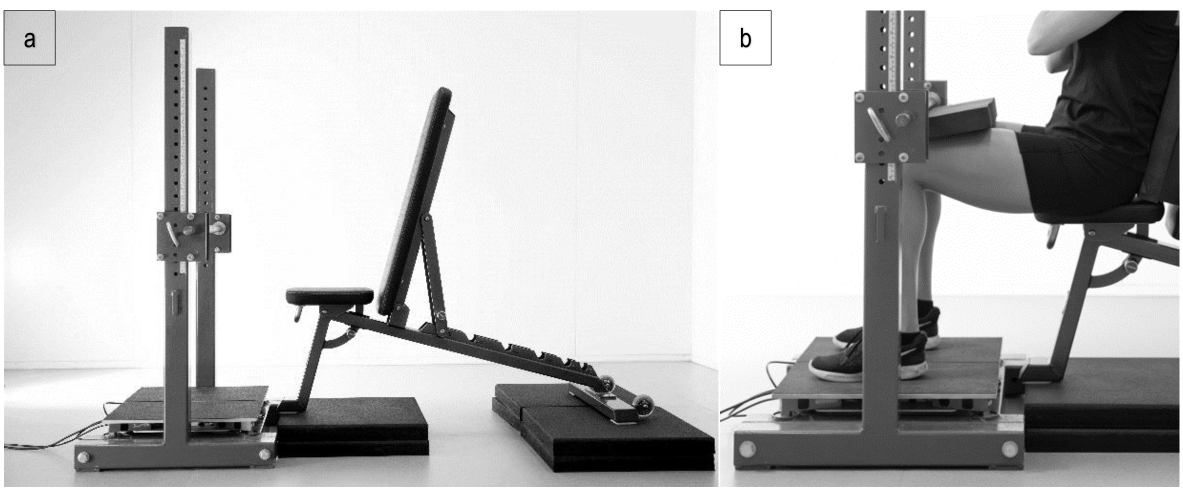

Figure 1. a. Isometric calf-raise rig set up, without participant. b. Participant applying a plantar flexion force and pressing knees into foam pad below rigid bar.

Weight-bearing lunge test

Following a dynamic warm-up (consisting of 5 minutes of single and double-leg calf raises, ballistic bounces and ankle circles), the weight bearing lunge test (WBLT) was performed as a measure of dorsiflexion range of motion on both ankles at baseline and following recovery. Participants placed their foot along a measuring tape which was secured to the floor and aligned perpendicular to a wall, with both their toe and heel on the centre line of the measuring tape. Participants were then asked to progressively move their toe further back from the wall on the measuring tape, repeating the lunge movement until the maximum distance at which they could tolerably lunge their knee to the wall without heel lift, was found. Measurement was made using the tape measure from the tip of their big toe to the wall, in centimetres. The WBLT is a functional and reliable method to indirectly assess dorsiflexion by measuring the maximal advancement of the tibia over the rearfoot in a weight-bearing position (Bennell et al., 1998). Previous investigators have reported robust inter-tester and intra-tester reliability associated with the assessment of WBLT performance in healthy adults, with high levels of test-retest reliability demonstrated (standard error of measurement = 1.1°, 95% CI = 2.2) (Bennell et al., 1998).

Single-leg calf-raise to exhaustion

To assess the strength-endurance of the calf muscles, a single-leg calf raise test to exhaustion was performed pre-exercise (baseline) and post-recovery (Figure 1). The calf-raises were completed in time with a metronome set at 60 bpm, with one minute rest between legs. The order of leg being tested (CON vs COMP) was randomised across participants but kept the same for each timepoint for the individual. The participant commenced the test by standing on one leg, with ankle in a neutral position (0°) and knee at full extension. Participants were instructed to complete as many repetitions of a single leg calf raise (as high as possible, or maximum range of motion) as they could. Participants were allowed to use their fingers on a wall to balance but were not allowed to apply any downward pressure on the wall to assist their movement. The order of leg being tested was randomised across participants but kept the same for each timepoint for the individual. Failure to complete a full range-of-motion calf-raise repetition in time with the metronome, or volitional exhaustion were the two reasons for terminating the test. The number of repetitions to exhaustion on each leg was recorded for analysis across the two time points. The calf-raise test has previously shown high test-retest reliability in healthy adults, with ICC's ranging from 0.78 to 0.99 and standard error of measurements ranging from two to six repetitions (Hébert-Losier et al., 2017).

Isometric calf-raise force

Left and right-leg isometric strength measures at baseline, post-exercise and post-recovery were obtained from a dual force-platform system (FDLite Dual Force Platforms, VALD Performance, Albion, Australia) housed in a custom-built isometric calf-raise rig (Figure 2a). This method has previously demonstrated high reliability (ICC = 0.94; CV 6.1%) for bilateral assessment of plantarflexion strength (Mattiussi et al., 2022). The rig allowed for stepwise changes in bar height, with the bar made of 4140 high tensile steel as described in a previous investigation (McCormick et al., 2022). Participants were seated on an adjustable weight bench centred between the force platforms and maintained hip and knee flexion at 90-degrees with feet hip-width apart and centred on each platform. A soft foam pad was placed over the knees for comfort during testing. The researcher then adjusted the metal bar until it was firmly resting on the foam pad and centred over the knees and secured the bar position with crocodile pins on the racking system. The bar height was recorded for each participant and repeated for subsequent testing. Participants were instructed to cross their hands over their shoulders and maintain an upright, vertical posture during isometric calf-raise testing. Participants were instructed to perform a maximal plantar flexion pushing against the foam pad on top of their knees (Figure 2b) following a verbal "*3, 2, 1*" countdown, as has been done previously (Rhodes et al., 2022; Warneke et al., 2022). Prior to the first test, participants completed two warm-up efforts corresponding to 50% and 75% effort to familiarise themselves with the movement and bar position. Participants then completed three maximal isometric calf raises holding for 3 seconds each, with 10 seconds rest in between. Participants were verbally encouraged in the same manner during each repetition to encourage maximal force production. Data was recorded using ForceDecks software (VALD Performance, Albion, Australia) and split into bilateral data obtained from each participant's left and right legs for analysis. The maximum recorded value for each participant was taken from each test for peak net vertical force and peak net force at 100 and 200 milliseconds.

Perceived muscle soreness

Perceived muscle soreness ratings were recorded pre and post exercise, post-recovery and 4-, 24- and 48-hours post-recovery (Figure 1). Ratings were obtained for each leg on a scale of one (no soreness) to ten (maximal soreness) (Thompson et al., 1999), while participants performed a single-leg calf raise. For the 4, 24 and 48 hours post recovery timepoints, participants were sent an electronic survey link (QuestionPro, Dallas, USA) via anonymised text message which contained the same instructions for completing the perceived muscle soreness scale for each leg.

Strenuous exercise bout

The exercise bout used to induce fatigue and subsequent muscle soreness was targeted at the calf muscles. In addition to the pre-exercise measures (which were also proposed to cause fatigue), participants were instructed to complete three sets of 20 double-leg calf raises at full range of motion off a platform height of 30cm. The calf-raises were completed in time with a metronome set at 60 bpm, with one minute rest between the sets. Participants were monitored to ensure that full range of motion was being achieved for each repetition. As with the single-leg calf raise to exhaustion, participants were allowed to use their fingers on a wall to balance but were not allowed to apply any downward pressure on the wall to assist their movement.

Compression sock recovery (COMP)

Immediately following the post-exercise testing timepoint (Figure 1), participants performed a recovery intervention on one of their legs (COMP), while the other leg had no recovery intervention (CON). The recovery intervention utilised in the current study involved a 30-minute application of a unisex compression sock to one leg only while seated. Sock size was determined by manufacturer guidelines using participant shoe size and calf circumference. The applied interface pressure of the compression socks was assessed at two standard anthropometric sites (medial malleolus and maximum calf circumference) on the participant's right leg upon first wear using the Kikuhime pressure monitor (MediGroup, Melbourne, Australia). The Kikuhime pressure monitor has previously been shown to be both valid and reliable (Brophy-Williams et al., 2014).

Belief effect

Before the testing session, participants were asked to rate their perception on whether "*compression garments would improve recovery following exercise*" on a continuous, 10-cm visual analog scale, ranging from strongly disagree (0 cm) to strongly agree (10 cm). Participants were then categorised as having "*high belief*" or "*low belief*" based on a cut-off of 5 cm on this scale. Care was taken throughout the testing session so as not to influence participants' perceptions of the use of compression garments.

Procedures

A repeated-measure, single-group design was used for the present study. Participants were allocated experimental (compression sock recovery - COMP) and control (passive recovery - CON) legs in a randomized, counterbalanced design. Participants completed single-leg isometric strength and perceptual measures before and after a strenuous bout of lower-limb exercises and then again immediately after the recovery intervention. Range of motion, limb circumference and single leg calf-raise to exhaustion tests were performed at baseline and post recovery (Figure 1). Additionally, perceptual measures of muscle soreness were taken again at 4, 24 and 48-hours post exercise. Participants completed all testing within a 1.5-hour period and were asked to avoid strenuous lower-body exercise for 24 hours prior and 24 hours after the study to limit any influence on perceived muscle soreness measures or physical testing procedures.

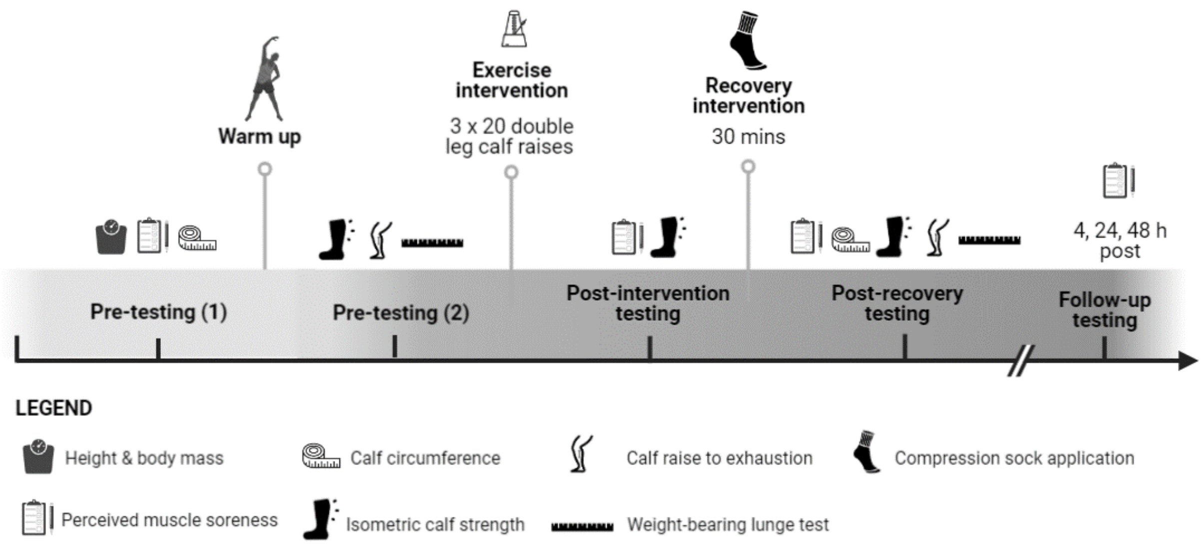

Figure 2. Testing timeline.

Statistical analyses

Descriptive statistics (means and standard deviations) for perceived muscle soreness (AU), isometric net peak force (N), calf raise repetitions (no.), knee-to-wall (cm) and calf girth (cm) were computed for various time points. A linear mixed model (LMM) was conducted to examine the effects of the recovery intervention (COMP vs CON) on these measures. The LMM included a fixed effect of time (2-6 levels, dependent on the variable) and a random intercept for participant ID. The assumption of normality was assessed with a visual inspection of a Q-Q plot, with the residuals being deemed to approximate a normal distribution. No interaction effect was recorded for time x intervention for any of the testing measures, thus the model was refit without the interaction term. The mean difference in the outcomes from baseline level to each time point was calculated and a 95% confidence interval was used to denote the imprecision of model parameter estimates.

Sensitivity analysis via a two-way repeated measures ANOVA was also conducted to ensure the results of the LMM were robust. The statistical significance was set at $p \leq .05$, and all data are presented as mean and standard deviation (±*SD*), unless stated otherwise. In addition, effect size statistics were performed to determine differences between GUN and CON groups at each time point. For these measures, the standardized change in mean between time points was calculated and expressed as standardized (Cohen's *d*) effects. The magnitude of each effect size was interpreted using thresholds of 0.2, 0.5, and 0.8 for *small*, *moderate*, and *large*, respectively (Cohen, 2013). 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.* All statistical analyses were conducted using the Jamovi statistical package (Jamovi Version 1.8.1, Jamovi Project, 2021).

RESULTS

The average applied pressure of the compression socks used in the study was 23.1 ± 6.4 mmHg at the medial malleolus and 16.5 ± 3.7 mmHg at the maximal calf circumference (Table 1).

Table 1. Average applied pressure of compression socks used in the present study (presented as mean ± SD).

	Females (n = 29)	Males (n = 29)	All participants
Applied pressure at medial malleolus (mmHg)	23.6 ± 5.1	22.5 ± 7.6	23.1 ± 6.4
Applied pressure at maximal calf circumference (mmHg)	16.7 ± 3.4	16.3 ± 4.1	16.5 ± 3.7

There was no statistically significant interaction between group and time on perceived muscle soreness (F(5, 571) = 0.68082, *p* = .638). However, there was a main effect of time on perceived muscle soreness (F(5, 574) = 66.88, *p* < .001), being significantly greater at each respective timepoint compared to baseline (Figure 3). There was a *small* difference in perceived muscle soreness in COMP compared to CON at the post-recovery timepoint, where perceived muscle soreness was lower in CON (0.29 ± 0.34, *p* = .638) (Figure 3).

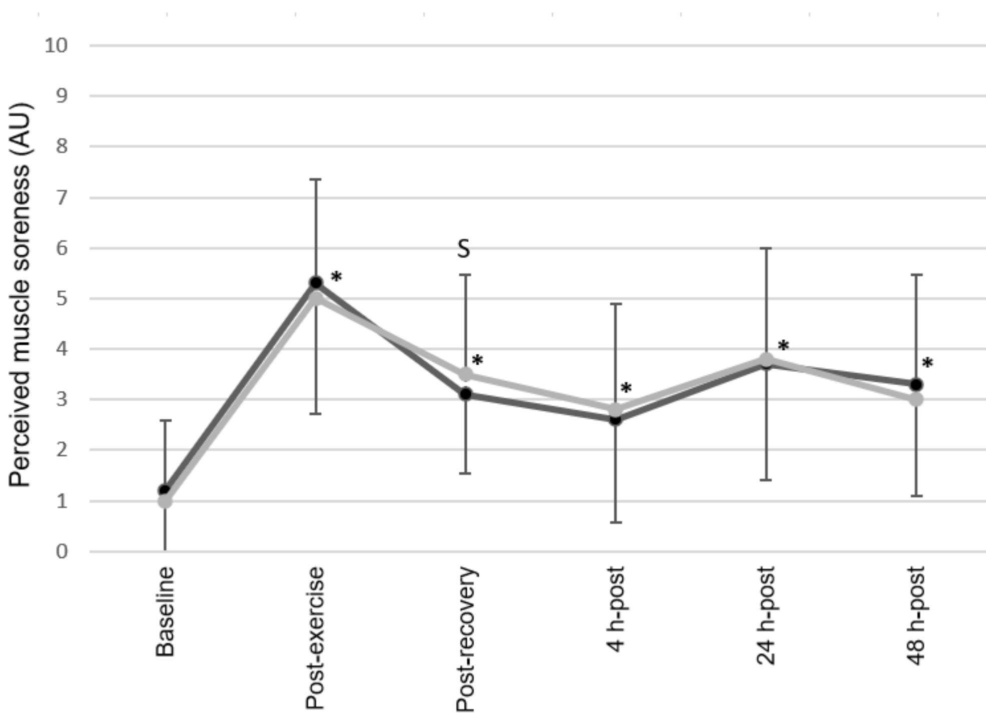

Figure 3. Changes in perceived muscle soreness across 48-hour period following strenuous exercise using short-term compression (COMP) or control (CON) recovery interventions. COMP = black line, CON = grey line. S = small effect size in favour of COMP; * = significant (*p* < .05) difference from baseline for both groups.

There were no statistically significant interactions between group and time on weight-bearing lunge test result (F(1,114) = 0.262, *p* = .610, partial η^2 = 0.000), calf circumference (F(1,114) = 0.924, *p* = .338, partial η^2= 0.008), and single leg calf raises to exhaustion (F(1,114) = 0.436, *p* = .511, partial η^2 = 0.004), with unclear effect sizes (Table 2). Additionally, there were no statistically significant interactions between group and time on isometric peak net calf raise force ($F(2,216) = 0.0118$, $p = .988$, partial $\eta^2 = 0.000$), isometric net force at 100ms ($F(2,216) = 0.4410$, $p = .644$, partial $\eta^2 = 0.004$), and isometric net force at 200ms ($F(2,216) = 0.192$, $p = .825$, partial $\eta^2 = 0.002$) and unclear effect sizes. However, there were significant main effects for time on both calf circumference ($F(1, 114) = 4.244$, $p = .04$) and calf endurance ($F(1, 114) = 18.006$, $p = <.001$). Specifically, calf circumference at post-recovery (37.1 cm, range: 36.6 – 37.6 cm) was greater than baseline (37.0 cm; range: 36.5 – 37.5 cm) compared to post-recovery; and the number of calf raises completed at post-recovery (34; range 32 - 37) was lower than completed at baseline (38; range 36 - 41).

When considering the participants' prior belief in compression garments, 41 participants (70.7%) were categorised as having "*high belief*" (> 5cm on visual analog scale), compared to 15 participants (25.9%) with "*low belief*" (≤ 5cm on visual analog scale); while 2 participants did not record a response for this question. "*Belief*" was subsequently introduced to the LMM as a covariate, however, no significant main effect was recorded.

Table 2. Summary of measures for control (CON) and compression sock (COMP) conditions (presented as mean ± SD).

	Time point	CON	COMP	Group x Time interaction	
				***p*-value**	**ES (*d*) ±95% CI**
Weight-bearing lunge test (cm)	Baseline	11.0 ± 3.6	11.2 ± 2.8	.610	-0.03 ± 0.10, *unclear*
	Post-recovery	10.9 ± 3.5	11.2 ± 3		
Calf circumference (cm)	Baseline	36.9 ± 2.6	37.1 ± 2.6	.513	-0.05 ± 0.08, *unclear*
	Post-recovery	37.1 ± 2.6	37.1 ± 2.6		
Net vertical force at 100ms (N)	Baseline	136.5 ± 68.7	137.8 ± 62.89	.644	
	Post-exercise	141.6 ± 64.2	135.4 ± 68.2		0.12 ± 0.29, *trivial*
	Post-recovery	143.0 ± 63.7	133.9 ± 57.1		0.16 ± 0.29, *trivial*
Net vertical force at 200ms (N)	Baseline	407.4 ± 168.5	409.1 ± 164.2	.825	
	Post-exercise	406.3 ± 161.8	392.0 ± 168.8		0.10 ± 0.25, *trivial*
	Post-recovery	405.2 ± 162.1	395.0 ± 158.6		0.07 ± 0.27, *trivial*
Peak net vertical force (N)	Baseline	839.7 ± 248.6	860.1 ± 259.7	.988	
	Post-exercise	800.6 ± 258.3	824.5 ± 288.7		-0.01 ± 0.23, *unclear*
	Post-recovery	840.7 ± 283.6	856.1 ± 304.5		0.02 ± 0.27, *unclear*
Single leg calf raise to exhaustion (no. completed)	Baseline	37.6 ± 12.1	38.7 ± 14.2	.511	-0.09 ± 0.22, *unclear*
	Post-recovery	33.1 ± 14.1	35.4 ± 15.4		
Perceived muscle soreness (AU)	Baseline	1.0 ± 1.1	1.2 ± 1.2	.638	
	Post-exercise	5.0 ± 2.3	5.3 ± 2.3		-0.04 ± 0.37, *unclear*
	Post-recovery	3.5 ± 2.1	3.1 ± 1.9		0.29 ± 0.34, *small*
	4 h-post	2.8 ± 2.2	2.6 ± 2.0		0.18 ± 0.37, *trivial*
	24-h post	3.8 ± 2.5	3.7 ± 2.6		0.11 ± 0.49, *trivial*
	48-h post	3.0 ± 2.5	3.3 ± 2.7		-0.09 ± 0.54, *trivial*

DISCUSSION

The aim of the current study was to evaluate the effects of an acute application of compression socks on perceptual and physical recovery in active adults following strenuous calf exercise. The findings suggest that a 30-minute recovery period with compression socks appears to have little effect on measures of ankle range of motion, calf circumference, isometric strength, or calf endurance when applied immediately following an exercise task. The use of these compression garments for acute recovery may result in a *small* decrease in perceived muscle soreness immediately following use, though this difference was not statistically significant. In contrast to previous research (Brophy-Williams et al., 2017; Stickford et al., 2015) there was no significant effect of prior belief in compression garments on their efficacy for recovery.

The main observation in the present study is that physical parameters including ankle range of motion, calf circumference, isometric strength and calf endurance were not significantly improved with the use of compression socks for acute recovery following strenuous calf exercise. The compression socks used in the present study exerted an applied pressure that was consistent with previous research (Broatch et al., 2019; Brophy-Williams et al., 2017). Therefore, the short recovery period implemented is likely a contributing factor to the lack of positive effect of the socks. This 30-minute period with compression socks may have been insufficient to promote positive changes to blood lactate, limb swelling, or skeletal muscle membrane turnover that have previously been reported from a minimum 60 minutes of compression wear (Broatch et al., 2019; Brophy-Williams et al., 2017; Montoye et al., 2021; Trenell et al., 2006). In addition, previous research has demonstrated that improvements to limb perfusion with compression are reversed within one minute of the compressive force being removed (Bochmann et al., 2005), which may limit the effectiveness of the garments on subsequent measures of physical performance.

Although there were no changes to physical parameters, there appears to have been a *small* decrease in perceived muscle soreness immediately following the 30-minute recovery period with compression socks when compared to the control condition. This is in agreement with previous research using compression socks for a 60-minute recovery period between treadmill running trials, which reported *small* improvements in perceived fatigue and overall perceived recovery, as well as a significant reduction in perceived muscle soreness (Brophy-Williams et al., 2017). It has previously been hypothesised that the application of compression garments following exercise may attenuate the release of creatine kinase into skeletal muscle and prevent oedema formation (Kraemer et al., 2001). In this way, the immediate use of compression socks after strenuous calf exercise may have led to minor changes in inflammatory and repair processes, contributing to a temporary reduction in perceived muscle soreness. However, no differences in perceived muscle soreness were apparent at the 4, 24 and 48-hour follow-up points, during which time this measure remained significantly elevated compared to baseline levels in both groups. This pattern is characteristic of delayed-onset muscle soreness (DOMS), which generally peaks approximately 48-hours post-exercise (Schoenfeld & Contreras, 2013).

The lack of effect of the compression socks on follow-up indices of perceived muscle soreness may reflect a systemic healing response from the body regardless of the compression garment being applied to one limb only, which has previously been show in an investigation of a similar design to the present study (within-subject crossover with an "*experimental*" and a "*control*" leg) (Heiss et al., 2018). While this may be a potential drawback, the study design does address inter-individual differences in DOMS and may overcome some of the potential "*placebo effect*" of wearing compression garments (Leabeater et al., 2022). Overall, compression socks may be useful for athletes seeking a practical, short-term recovery intervention in between training sessions, with a focus on reducing perceived muscle soreness, though this likely would not result in any significant improvements in lower-limb functional capacity.

In contrast to previous research, participants' prior beliefs on the efficacy of compression garments for recovery in the present study had little influence on their performance in various physical tasks following the recovery period. Brophy-Williams et al.(Brophy-Williams et al., 2017) observed that "*believers*" in compression garments were more likely to maintain their subsequent running performance after wearing the garments for recovery than "*non-believers*", highlighting the contribution of expectancy on the success of recovery/performance interventions in sport. Similarly, Stickford et al. (2015) observed variable responses in running mechanics based on participants' belief in and experience with compression garments and suggested that both these factors should be considerations prior to use of the garments. In the present study, as in Brophy-Williams et al. (2017), the majority of participants were "*high believers*" in compression garments, consistent with the widespread use of these garments by athletes for performance and recovery (Driller & Brophy-Williams, 2016).

Some limitations should be considered when interpreting the results of this study. Firstly, participants' dietary intake was not tracked or controlled for prior to the study or during the 48-hour follow-up period, which may have influenced muscular recovery. Given that perceived muscle soreness exhibits variability across muscle groups (Schoenfeld & Contreras, 2013), the results of the present study should be considered specific to the calf muscles only. In addition, it is possible that a learning effect was apparent on the isometric calf-raise task which may have influenced results across the testing timeline, as only a brief familiarisation was undertaken on this apparatus prior to baseline testing. While a reduction in physical capacity following the strenuous calf exercise was apparent (by way of reduced calf endurance and increased calf circumference), there is a possibility that this exercise task did not induce significant muscle fatigue and soreness in all participants, which is an ongoing consideration for recovery intervention research (Barnett, 2006).

CONCLUSIONS

The results of the present study indicate that a 30-minute application of compression socks for recovery has little effect on measures of ankle range of motion, calf circumference, isometric strength, or calf endurance following a strenuous bout of calf exercise. However, compression socks may result in a *small* decrease in perceived muscle soreness immediately following their use for recovery. Therefore, these garments may be an option for individuals seeking to reduce perceived muscle soreness with a short timeframe in between training bouts, though there is limited transfer to other measures of physical performance.

AUTHOR CONTRIBUTIONS

Alana Leabeater: Conceptualization, methodology, formal analysis, investigation, writing (original draft), visualization; Lachlan James & Matthew Driller: Conceptualization, methodology, investigation, writing (review & editing), supervision; Anthea Clarke: methodology, investigation, writing (review & editing), supervision; Minh Huynh: formal analysis, writing (review & editing).

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DISCLOSURE STATEMENT

The authors report there are no competing interests to declare. The compression socks used in the current study were supplied by the company (Pressio Inc., London, United Kingdom) free of charge, however the company had no input into the design, analysis or reporting of results from this study.

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REFERENCES

Barnett, A. (2006). Using recovery modalities between training sessions in elite athletes. Sports Medicine, 36(9), 781-796. https://doi.org/10.2165/00007256-200636090-00005

Bennell, K., Talbot, R., Wajswelner, H., Techovanich, W., Kelly, D., & Hall, A. J. (1998). Intra-rater and inter-rater reliability of a weight-bearing lunge measure of ankle dorsiflexion. Australian Journal of Physiotherapy, 44(3), 175-180. https://doi.org/10.1016/S0004-9514(14)60377-9

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. https://doi.org/10.1152/japplphysiol.00965.2004

Broatch, J. R., Bishop, D. J., Zadow, E. K., & Halson, S. (2019). Effects of Sports Compression Socks on Performance, Physiological, and Hematological Alterations After Long-Haul Air Travel in Elite Female Volleyballers. J Strength Cond Res, 33(2), 492-501. https://doi.org/10.1519/jsc.0000000000003002

Brophy-Williams, N., Driller, M., Halson, S., Fell, J. W., & Shing, C. (2014). Evaluating the Kikuhime pressure monitor for use with sports compression clothing. Sports Engineering, 17(1), 55-60. https://doi.org/10.1007/s12283-013-0125-z

Brophy-Williams, N., Driller, M. W., Kitic, C. M., Fell, J. W., & Halson, S. L. (2017). Effect of Compression Socks Worn Between Repeated Maximal Running Bouts. International Journal of Sports Physiology & Performance, 12(5), 621-627. https://doi.org/10.1123/ijspp.2016-0162

Carmont, M., Silbernagel, K. G., Mathy, A., Mulji, Y., Karlsson, J., & Maffulli, N. (2013). Reliability of Achilles tendon resting angle and calf circumference measurement techniques. Foot and Ankle Surgery, 19(4), 245-249. https://doi.org/10.1016/j.fas.2013.06.007

Chatard, J.-C., Atlaoui, D., Farjanel, J., Louisy, F., Rastel, D., & Guézennec, C.-Y. (2004). Elastic stockings, performance and leg pain recovery in 63-year-old sportsmen. European Journal of Applied Physiology, 93(3), 347-352. https://doi.org/10.1007/s00421-004-1163-9

Cohen, J. (2013). Statistical power analysis for the behavioral sciences. Routledge. https://doi.org/10.4324/9780203771587

da Silva Chiappa, G. R. (2021). Effect of resistance exercise with arm sleeve compression garments accelerates blood lactate removal. Manual Therapy, Posturology & Rehabilitation Journal, 1-4. https://doi.org/10.17784/mtprehabjournal.2021.19.1220

Driller, M. W., & Brophy-Williams, N. N. (2016). Journal of Athletic Enhancement The Use of Compression Garments in Elite Australian Athletes: A Survey. https://doi.org/10.4172/2324-9080.1000228

Galanaud, J. P., Laroche, J. P., & Righini, M. (2013). The history and historical treatments of deep vein thrombosis. Journal of Thrombosis and Haemostasis, 11(3), 402-411. https://doi.org/10.1111/jth.12127

Hébert-Losier, K., Wessman, C., Alricsson, M., & Svantesson, U. (2017). Updated reliability and normative values for the standing heel-rise test in healthy adults. Physiotherapy, 103(4), 446-452. https://doi.org/10.1016/j.physio.2017.03.002

Heiss, R., Hotfiel, T., Kellermann, M., May, M. S., Wuest, W., Janka, R., Nagel, A. M., Uder, M., & Hammon, M. (2018). Effect of Compression Garments on the Development of Edema and Soreness in Delayed-Onset Muscle Soreness (DOMS). J Sports Sci Med, 17(3), 392-401.

Hirai, M. (1999). The effect of posture and exercise on elastic stocking compression at different sites of the leg. Vasa, 28(3), 190-194. https://doi.org/10.1024/0301-1526.28.3.190

Kellmann, M., & Beckmann, J. (2018). Sport, recovery, and performance. Interdisciplinary insights. https://doi.org/10.4324/9781315268149

Kellmann, M., Bertollo, M., Bosquet, L., Brink, M., Coutts, A. J., Duffield, R., Erlacher, D., Halson, S. L., Hecksteden, A., & Heidari, J. (2018). Recovery and performance in sport: consensus statement. International journal of sports physiology and performance, 13(2), 240-245. https://doi.org/10.1123/ijspp.2017-0759

Kraemer, W. J., Bush, J. A., Wickham, R. B., Denegar, C. R., Gomez, A. L., Gotshalk, L. A., Duncan, N. D., Volek, J. S., Putukian, M., & 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. https://doi.org/10.2519/jospt.2001.31.6.282

Leabeater A. J., James L. P., Driller M. W. (2022) Tight Margins: Compression Garment Use during Exercise and Recovery - A Systematic Review. Textiles. 2(3):395-421. https://doi.org/10.3390/textiles2030022

Lee, D. C. W., Sheridan, S., Ali, A., Sutanto, D., & Wong, S. H. S. (2021). Wearing compression tights post-exercise enhances recovery hemodynamics and subsequent cycling performance. Eur J Appl Physiol. https://doi.org/10.1007/s00421-021-04661-0

Mattiussi, A. M., Shaw, J., Cohen, D. D., Price, P., Brown, D. D., Pedlar, C., & Tallent, J. (2022). Reliability, variability, and minimal detectable change of bilateral and unilateral lower extremity isometric force tests. Journal of Sport and Exercise Science.

McCormick, B., Talpey, S., James, L., & MacMahon, C. (2022). The Influence of Instruction on Isometric Mid-Thigh Pull Force-Time Variables. International Journal of Strength and Conditioning, 2(1). https://doi.org/10.47206/ijsc.v2i1.134

Montoye, A. H., Mithen, A. A., Westra, H. L., Besteman, S. S., & Rider, B. C. (2021). The Effect of Compression Socks on Maximal Exercise Performance and Recovery in Insufficiently Active Adults. International Journal of Exercise Science, 14(7), 1036.

Rhodes, D., Jeffery, J., Brook-Sutton, D., & Alexander, J. (2022). Test-Retest Reliability of the Isometric Soleus Strength Test in Elite Male Academy Footballers. International Journal of Sports Physical Therapy, 17(2), 286. https://doi.org/10.26603/001c.31047

Rosso, C., Vavken, P., Polzer, C., Buckland, D. M., Studler, U., Weisskopf, L., Lottenbach, M., Müller, A. M., & Valderrabano, V. (2013). Long-term outcomes of muscle volume and Achilles tendon length after Achilles tendon ruptures. Knee Surgery, Sports Traumatology, Arthroscopy, 21(6), 1369-1377. https://doi.org/10.1007/s00167-013-2407-1

Schoenfeld, B. J., & Contreras, B. (2013). Is postexercise muscle soreness a valid indicator of muscular adaptations? Strength & Conditioning Journal, 35(5), 16-21. https://doi.org/10.1519/SSC.0b013e3182a61820

Shimokochi, Y., Kuwano, S., Yamaguchi, T., Abutani, H., & Shima, N. (2017). Effects of Wearing a Compression Garment During Night Sleep on Recovery From High-Intensity Eccentric-Concentric Quadriceps Muscle Fatigue. J Strength Cond Res, 31(10), 2816-2824. https://doi.org/10.1519/jsc.0000000000002116

Stickford, A. S., Chapman, R. F., Johnston, J. D., & Stager, J. M. (2015). Lower-leg compression, running mechanics, and economy in trained distance runners. International journal of sports physiology and performance, 10(1), 76-83. https://doi.org/10.1123/ijspp.2014-0003

Thompson, D., Nicholas, C., & Williams, C. (1999). Muscular soreness following prolonged intermittent high-intensity shuttle running. Journal of Sports Sciences, 17(5), 387-395. https://doi.org/10.1080/026404199365902

Trenell, M. I., Rooney, K. B., Sue, C. M., & Thomspon, C. H. (2006). Compression Garments and Recovery from Eccentric Exercise: A (31)P-MRS Study. J Sports Sci Med, 5(1), 106-114.

Warneke, K., Keiner, M., Lohmann, L., Hillebrecht, M., Wirth, K., & Schiemann, S. (2022). The Influence of Maximum Strength Performance in Seated Calf Raises on Counter Movement Jump and Squat Jump in Elite Junior Basketball Players. Sport Mont J, 20, 63-68. https://doi.org/10.26773/smj.220610

Weakley, J., Broatch, J., O'Riordan, S., Morrison, M., Maniar, N., & Halson, S. L. (2021). Putting the squeeze on compression garments: current evidence and recommendations for future research: a systematic scoping review. Sports Medicine, 1-20. https://doi.org/10.1007/s40279-021-01604-9