



Original research

Wearing compression socks during exercise aids subsequent performance[☆]



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ABSTRACT

Objectives: To assess the effect of wearing compression socks on immediate and subsequent 5 km running time trials, with particular attention to the influences on physiological, perceptual and performance-based parameters.

Design: Counter-balanced cross-over experiment.

Methods: Twelve male runners (mean \pm SD 5 km run time 19:29 \pm 1:18 min:s) each completed two experimental sessions. Sessions consisted of a standardised running warm-up, followed by a 5 km time trial (TT1), a one hour recovery period, then a repeat of the warm-up and 5 km time trial (TT2). One session required the use of sports compression socks during the first warm-up and time trial (COMP), while the other did not (CON).

Results: The decline in run performance in CON from TT1 to TT2 was moderate and significantly greater than that experienced by runners in COMP (9.6 s, $d = 0.67$, $p < 0.01$). No difference was found between experimental conditions for oxygen consumption, blood lactate or calf volume ($p = 0.61, 0.54, 0.64$, respectively). Perceptual measures of muscle soreness, fatigue and recovery were also similar between trials ($p = 0.56, 1.00$ & 0.61 , respectively).

Conclusions: Wearing sports compression socks during high intensity running has a positive impact on subsequent running performance. The underlying mechanism of such performance enhancement remains unclear, but may relate to improved oxygen delivery, reduced muscle oscillation, superior running mechanics and athlete beliefs.

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1. Introduction

Compression garments have long been used in the medical industry for their ability to improve circulation,¹ and therefore, venous return.² More recently, the use of compression garments has become widespread among athletes in both performance and recovery-based settings,³ with a wide range of garment types investigated, including knee-high socks, calf sleeves, shorts, tights

and upper body compression.³ Sports compression garments are proposed to reduce muscle oscillation when used during exercise, and hence limit muscle damage; as well as improving running economy, therefore proving beneficial to performance.^{4,5}

Changes in running economy brought about by compression garments may be related to several mechanisms, including reductions in metabolic requirements, greater proprioception and increased muscular support.^{6,7} Two investigations have revealed no changes in the metabolic cost of running when compression garments encapsulating the calves were worn while running at submaximal speeds.^{8,9} However, Bringard et al.¹⁰ found improved running economy at 12 km h⁻¹, yet not at faster or slower speeds. These equivocal findings suggest that the precise mechanisms behind potential improvements in running economy are yet to be clearly elucidated, and other changes, such as enhanced pro-

Abbreviations: COMP, compression condition; CON, control condition; CSA, cross-sectional area; RPE, rating of perceived exertion; TQR, Total Quality Recovery scale; TT, time trial.

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proprioceptive feedback and psychological factors, brought about by compression garments may influence outcomes.

The capacity for compression garments to increase venous return is proposed to allow more efficient oxygen delivery to fatigued muscles, hasten the removal of metabolites built up during exercise,⁵ and therefore reduce cardiac load for a set work output.⁸ This reduction in metabolic cost can be illustrated through surrogate measures such as lower blood lactate and heart rate for a given workload.⁸ However, these findings seem to be contrary to the norm, with recent reviews concluding that compression garments have little or no effect on blood lactate and heart rate.^{3,11} It is likely that any small changes brought about by compression garments during exercise are overshadowed by the large increase in blood flow to the limbs during exercise, which may be up to 10-fold compared to rest.¹²

Performance may be enhanced by the increase in proprioceptive feedback provided by compression garments.¹³ Improved proprioception allows for more efficient movement, as has been illustrated by the capacity for below-knee compression socks to increase movement accuracy.¹⁴ Movement efficiency is particularly relevant to endurance-based activities like distance running, that require thousands of repeated cyclical actions.

Reducing muscle oscillations during exercise is also proposed to improve movement efficiency.¹⁰ Compressions shorts have been shown to support the muscle belly and reduce movements during training.¹⁵ This reduction in movement may promote lower energy expenditure.¹⁰ However, no clear link has been forged between changes in muscle oscillation and endurance performance, as research in this area has focused primarily on explosive sprinting and jumping movements while wearing compression applied to the upper leg.¹⁶ While the link between muscle oscillation and endurance performance is unclear, it is possible that exercise associated inflammation and soreness could be limited by a reduction in muscle movement.¹⁷ Although several investigators^{10,18} have alluded to this phenomenon, no clear connection has been displayed between changes in muscle oscillation, improved recovery and subsequent performance.

This study aimed to assess the effect of wearing compression socks during a 5 km running time trial on physiological, perceptual and performance-based parameters. In addition, the capacity for compression socks to impact subsequent performance was also investigated.

2. Methods

Twelve well-trained male runners (mean \pm SD; 5 km run time 19:29 \pm 1:18 min:s, height 181.4 \pm 6.9 cm, body mass 77.8 \pm 6.5 kg, age 30.5 \pm 8.1 years) participated in the current study. All runners were briefed on the requirements of taking part in the study before consent was provided. The study procedures complied with the Declaration of Helsinki and were approved by the Australian Institute of Sport and University of Tasmania Human Research Ethics Committees prior to data collection commencing.

Each runner attended a climate-controlled laboratory on three occasions: one familiarisation session and two experimental sessions. The experimental sessions were administered in a counter-balanced, crossover design. In order to control any dietary variables, runners completed a 24 h food diary prior to their first experimental session and were instructed to replicate their diet as closely as possible before the subsequent experimental session. Training was also controlled for, with runners keeping all training identical for 48 h before testing on all occasions. Runners were asked to refrain from strenuous exercise (<24 h) and caffeine (<12 h) and to arrive in a fully rested, hydrated state. All testing was performed on the same treadmill at the same time of day to mini-

mize diurnal variation, and participants wore the same footwear and exercise attire for every session. Each experimental session involved runners performing a standardised warm-up followed by a 5 km TT (TT1), then a one-hour recovery intermission before a second warm-up and 5 km TT (TT2). Familiarisation sessions involved the completion of just one warm-up protocol followed by a single 5 km TT.

Runners completed one experimental session wearing new compression socks (Performance Run Sock, 2XU, Melbourne, Australia) for the first warm-up and TT1 (COMP), and one experimental session with no compression socks (CON). Calf girth and foot size were measured for each runner so that they could be correctly fitted for sports compression garments according to manufacturers' recommendations. Pressure applied by the garment was assessed at three landmarks on the right leg, using the valid and reliable Kikuhime pressure monitoring device (MediGroup, Melbourne, Australia). Mean pressure (\pm SD) of the compression socks was 37 \pm 4 mmHg at the maximal calf girth, 31 \pm 4 mmHg at the upper ankle and 23 \pm 4 mmHg at the lower ankle, measured prior to the beginning of the COMP trial.

The exercise protocol is outlined in Fig. 1. The warm-up consisted of three four-minute blocks of submaximal running at 60, 70 and 80% of runner-reported 5 km race pace (mean speeds of 9.6 \pm 0.6, 11.1 \pm 0.7 & 12.7 \pm 0.8 km h⁻¹, respectively) on a custom-built, motorized treadmill (Australian Institute of Sport). A rest period of one-minute was implemented between each warm-up intensity. Following the warm-up, runners completed a maximal 5 km TT on the same treadmill (TT1). The same warm-up and a subsequent 5 km TT was performed 60-min later (TT2). The TTs began at a speed 1 km h⁻¹ slower than the predicted mean speed required for completion of a 5 km road race, as previously reported by runners. During the 5 km TT, runners were blinded to their elapsed time and run speed, and standardised, scripted encouragement was given by the researcher every 500 m. Runners were to indicate to the researcher for the speed to increase or decrease at any stage of the test by saying 'faster' or 'slower', whereby speed was adjusted by 0.5 km h⁻¹. Runners were also partially blinded to distance covered, with progress revealed every 500 m up until the final 500 m, whereupon they received updates for each 100 m run. Total time was recorded at the completion of the 5 km TTs and the difference between TT1 and TT2 was used as the main performance outcome measure. The reliability of a 5 km TT has been previously determined in our laboratory, with a typical error of 10.9 s and coefficient of variation of 1.0%.

During the 60-min recovery period a carbohydrate drink (Gatorade; 6% carbohydrate content) and muesli bars (Uncle Toby's; 20.5 g carbohydrate per bar) were provided to runners to be consumed ad libitum in their first experimental session, with consumption timing and amounts matched for the subsequent experimental session. Runners remained in a passive, seated position for the duration of the recovery period in both conditions.

Expired air was analysed throughout all three stages of the first warm-up using a custom-built open-circuit indirect calorimetry system with associated in-house software (Australian Institute of Sport). The final minute of each collection was used to assess running economy.

Blood lactate concentration (BLa) was measured via a capillary fingertip sample using a Lactate-Pro 2 analyser (Arkay, Shiga, Japan). Samples were collected at the completion of each stage of the warm-up protocol, as well as three minutes after the completion of both TT1 and TT2. Ratings of Perceived Exertion (RPE) were also collected at these time points.

Three-dimensional (3D) laser body scans (Vitus Smart XXL, Human Solutions; Kaiserslautern) were used to assess any changes in cross-sectional area of the calf. Repeat scans were taken without compression before the first warm-up and immediately after TT1.



Fig. 1. Experimental protocol. Warm-up intensities based on 60, 70 and 80% of self-predicted 5 km road race pace. COMP = compression condition (wearing compression socks); CON = control condition (no compression socks).

The Vitus Smart XXL 3D scanner has been reported as accurate and reliable.¹⁹

Before and after each warm-up and TT, runners performed a half-squat exercise, as described by Vaile et al.,²⁰ to promote general body awareness before rating their perceived muscle soreness and fatigue on a 10-point visual analogue scale (from 'no soreness at all' to 'extremely sore' and 'no fatigue at all' to 'extremely fatigued', respectively). Runners also rated their perceived recovery on the Total Quality Recovery scale (TQR)²¹ at the start and end of the recovery period.

SPSS Statistics Package (SPSS Statistics IBM, Version 20.0) was used for all data analyses. Normality was tested with the Kolmogorov–Smirnov test and violations of the assumption of sphericity were determined using Mauchly's Test of Sphericity. No violations were apparent. A paired t-test was used to determine that no order effect was apparent for the two conditions, with further t-tests to assess differences in time trial performance. Two-way repeated measures ANOVAs (time point*condition) were then performed to determine main effects for each of the remaining dependent variables (blood lactate, expired gases, calf CSA and perceptual assessments). Post-hoc analyses (t-tests) with Bonferroni corrections determined where specific differences occurred.

Practical differences in performance between conditions were identified by calculating standardised (Cohen's *d*) effect size scores and interpreting them using the following criteria: <0.2, *trivial*; 0.2–0.6, *small*; 0.6–1.2, *moderate*; 1.2–2.0, *large*; >2.0, *very large*.²² All results are presented as mean ±95% confidence limits unless otherwise stated.

3. Results

There was no significant difference in TT1 or TT2 performance between conditions (Table 1). A significant, yet *trivial*, decrement in run performance from TT1 to TT2 was evident for CON, while the change in performance in the COMP condition was considered to be *trivial* and non-significant. However, there was a *moderate* significant performance benefit for COMP when comparing the decline in run performance from TT1 to TT2 between conditions. No order effect was apparent for the two conditions ($p = 0.07$).

Oxygen consumption and blood lactate significantly increased over the course of the exercise protocol ($p < 0.001$ for both), but there was no main effect of condition ($p = 0.61$ and $p = 0.54$, respectively) or the interaction of time point*condition ($p = 0.34$ and $p = 1.00$, respectively, Table 2) for either variable. Oxygen consumption increased significantly, with each increment of the warm-up protocol ($d = 2.30$, $p < 0.01$ from stage 1 to 2 and $d = 2.46$, $p < 0.01$ from stage 2 to 3). Blood lactate did not differ from the first to the second stage of the warm-up ($d = 0.33$, $p = 1.00$), but increased significantly for the third stage ($d = 0.81$, $p < 0.01$). TT efforts resulted in significantly higher blood lactate measures than the warm-up

stages ($d = 2.80$, $p < 0.01$), but did not differ from TT1 to TT2 ($d < 0.01$, $p = 0.10$).

A main effect was apparent for time on perceived exertion ($p < 0.01$). Runners' perceived exertion increased significantly as the warm-up progressed ($d = 0.90$, $p < 0.01$), and both TT efforts corresponded with significantly higher exertion than any stage of the warm-up ($d = 3.19$, $p < 0.01$). However, there was no difference between conditions at each of these time points.

Runners perceived their muscle soreness and fatigue to be similar regardless of intervention ($p = 0.56$ & 1.00 , respectively). Both parameters did however change over time, with significant increases in soreness and fatigue from pre-TT to post-TT on both occasions ($d = 1.05$, $p < 0.01$ and $d = 1.75$, $p < 0.01$, respectively). During the recovery period, perceived soreness remained constant ($p = 0.14$), while fatigue was reduced over the 60-min period ($p < 0.01$). Perceptions of recovery were also unaltered by the use of compression socks, with TQRPer similar between conditions ($p = 0.61$). However, runner ratings did improve over the course of the recovery period ($d = 0.87$, $p = 0.01$).

Compression socks did not influence changes in calf cross-sectional area. There were no differences between conditions and no change in cross-sectional area from prior to warm-up 1 to immediately post-TT1 ($d = 0.01$, $p = 0.64$ and $d = 0.05$, $p = 0.22$, respectively).

4. Discussion

The primary finding from this investigation was that wearing compression socks during exercise can positively influence performance in a subsequent exercise bout (9.5 s in this population). This is a novel outcome, adding a further layer to research into sports compression garments, where the majority of previous investigations have studied the immediate effects of wearing compression garments during performance, or their efficacy when worn post-exercise.^{3,5,11}

The current study attempted to better understand any changes in running performance by assessing a multitude of mechanistic parameters that have previously been attributed to potential performance enhancements elicited by sports compression garments. Similar to the majority of previous investigations,^{18,23,24} blood lactate was not affected by the use of compression garments while running. Scientists have proposed that compression garments may enhance circulatory flow, and therefore hasten lactate removal,⁸ but this phenomenon is yet to be clearly displayed in an athletic setting. Oxygen consumption did not differ between experimental conditions either. This result is consistent with the findings of Rider et al.²⁴ and Stickford et al.,⁹ who both assessed the efficacy of compression garments while running on a treadmill. Similarly, assessments of calf CSA were no different between conditions in the present study, again reflecting previous research that has found no

Table 1
Summary of time trial performances for (CON) and compression (COMP) conditions.

	CON (mean \pm 95% confidence limits)	COMP (mean \pm 95% confidence limits)	Difference between conditions
TT1	19:24 \pm 0:51	19:32 \pm 0:48	No difference ($p = 0.18$, $d = 0.10$)
TT2	19:41 \pm 0:53	19:38 \pm 0:53	No difference ($p = 0.75$, $d = 0.03$)
Decrement from TT1 to TT2	15.9 \pm 8.5 s* ($p < 0.01$, $d = 0.19$)	6.4 \pm 1.9 s ($p = 0.08$, $d = 0.17$)	Moderate benefit* ($p < 0.01$, $d = 0.67$)

* Denotes significant difference, $p < 0.05$

Table 2
Summary of physiological measures for (CON) and compression (COMP) conditions (presented as mean \pm SD).

	Time point	CON	COMP	Difference between conditions
VO ₂ (ml kg ⁻¹ min ⁻¹)	Warm-up			No difference ($p = 0.61$)
	(Stage 1)	35.8 \pm 1.9	37.1 \pm 1.4	
	(Stage 2)	41.6 \pm 1.2	40.8 \pm 1.2	
	(Stage 3)	47.4 \pm 1.9	47.7 \pm 2.0	
BLa (mmol L ⁻¹)	Warm-up			No difference ($p = 0.54$)
	(Stage 1)	1.3 \pm 0.2	1.7 \pm 0.5	
	(Stage 2)	1.3 \pm 0.2	1.6 \pm 0.4	
	(Stage 3)	1.9 \pm 0.3	2.1 \pm 0.4	
	Post-TT1	9.2 \pm 1.7	9.3 \pm 2.2	
Cross sectional area (cm ²)	Post-TT2	7.5 \pm 1.4	7.8 \pm 2.6	No difference ($p = 0.63$)
	Pre-warm-up 1	115.8 \pm 6.7	116.1 \pm 6.7	
	Post-TT1	116.7 \pm 7.0	116.2 \pm 6.8	
ΔCSA		0.9 \pm 1.0	0.1 \pm 0.8	
RPE (6–20 scale)	Warm-up			No difference ($p = 0.56$)
	(Stage 1)	8.2 \pm 0.9	8.2 \pm 1.0	
	(Stage 2)	9.7 \pm 1.1	10.0 \pm 1.1	
	(Stage 3)	11.1 \pm 1.3	11.2 \pm 1.4	
	Post-TT1	18.0 \pm 1.3	18.2 \pm 1.2	
	Post-TT2	18.7 \pm 0.8	18.7 \pm 0.7	
Muscle soreness (1–10 scale)	Pre-warm-up 1	1.0 \pm 0.6	0.8 \pm 0.5	No difference ($p = 0.56$)
	Pre-TT1	1.6 \pm 0.9	1.6 \pm 0.6	
	Post-TT1	3.7 \pm 1.2	4.2 \pm 1.1	
	Pre-warm-up 2	4.0 \pm 1.3	3.2 \pm 0.7	
	Pre-TT2	4.6 \pm 1.1	3.7 \pm 0.8	
	Post-TT2	5.7 \pm 1.2	6.0 \pm 1.3	
Fatigue (1–10 scale)	Pre-warm-up 1	1.1 \pm 0.7	0.8 \pm 0.5	No difference ($p = 1.00$)
	Pre-TT1	2.0 \pm 0.7	1.8 \pm 0.7	
	Post-TT1	5.4 \pm 1.5	5.6 \pm 1.3	
	Pre-warm-up 2	3.6 \pm 1.1	3.3 \pm 0.7	
	Pre-TT2	4.3 \pm 0.9	4.5 \pm 0.9	
	Post-TT2	7.1 \pm 1.4	7.4 \pm 1.1	
TQRP (6–20 scale)	Post-TT1 1	10.6 \pm 0.2	11.4 \pm 0.2	No difference ($p = 0.61$)
	Pre-warm-up 2	13.9 \pm 0.2	13.8 \pm 0.2	
	ΔTQRP	3.3 \pm 2.4	2.4 \pm 1.9	

effect of compression garments on lower limb volume 5 min after the completion of 10 km and marathon running efforts.^{23,25}

Although the aforementioned parameters could not justify the performance changes in this study, other mechanisms may have affected running performance. Reducing the workload required from the athlete in the first exercise bout would have improved recovery and allowed superior performance in the subsequent TT. A reduction in workload may have been brought about by improved oxygen delivery,^{26,27} reduced muscle oscillation,¹⁵ and a decrease in cardiovascular demands due to enhanced circulatory flow.^{6,8} Hooper et al.²⁸ also suggested that compression garments increase proprioception, which may improve stride mechanics, therefore aiding biomechanical running economy and reducing potential muscle damage.²⁹ However, it must be recognised that this combination of outcomes is highly speculative, and focus must also be placed on the role that psychological factors, including a placebo effect, may play on athletic performance.

Surprisingly, the current study revealed no differences in perceptual measures between experimental conditions, unlike most previous research into the efficacy of compression garments. Several studies have reported athletes who wore compression gar-

ments during exercise to have experienced reductions in muscle soreness from 24 to 72 h post-activity.^{23,30} This disparity is likely due to the limited duration of the recovery period in the present study, which could have been too brief to realise any potential benefits of wearing compression socks while running.

5. Conclusion

In summary, wearing compression socks during high intensity running does not affect immediate performance. However, they have a positive impact on subsequent running performance. The underlying mechanism of such performance enhancement remains unclear, but may relate to improved oxygen delivery, reduced muscle oscillation and superior running mechanics.

Practical implications

- Wearing compression socks while running does not affect immediate performance.

- However, compression socks worn during exercise can augment subsequent exercise bouts, so should be considered when athletic performances are scheduled in short succession.
- Compression socks worn when running also have the capacity to augment post-exercise recovery.

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References

1. Benko T, Cooke EA, McNally MA et al. Graduated compression stockings: knee length or thigh length. *Clin Orthop Relat Res* 2001; 383:197–203.
2. Cooke EA, Benko T, O'Connell BM et al. The effect of graduated compression stockings on lower limb venous haemodynamics. *Phlebology* 1996; 11(4):141–145.
3. MacRae BA, Cotter JD, Laing RM. Compression garments and exercise: garment considerations, physiology and performance. *Sports Med* 2011; 41(10):815–843.
4. Hill J, Howatson G, van Someren K et al. Compression garments and recovery from exercise-induced muscle damage: a meta-analysis. *Br J Sports Med* 2014; 48(18):1340–1346.
5. Engel FA, Holmberg HC, Sperlich B. Is there evidence that runners can benefit from wearing compression clothing? *Sports Med* 2016; 46(12):1939–1952.
6. Driller MW, Halson SL. The effects of wearing lower body compression garments during a cycling performance test. *Int J Sports Physiol Perform* 2013; 8(3):300–306.
7. Born DP, Holmberg HC, Goernert F et al. A novel compression garment with adhesive silicone stripes improves repeated sprint performance – a multi-experimental approach on the underlying mechanisms. *BMC Sports Sci Med Rehabil* 2014; 6(21):21.
8. Varela-Sanz A, Espana J, Carr N et al. Effects of gradual-elastic compression stockings on running economy, kinematics, and performance in runners. *J Strength Cond Res* 2011; 25(10):2902–2910.
9. Stickford AS, Chapman RF, Johnston JD et al. Lower-leg compression, running mechanics, and economy in trained distance runners. *Int J Sports Physiol Perform* 2015; 10(1):76–83.
10. Bringard A, Perrey S, Belluye N. Aerobic energy cost and sensation responses during submaximal running exercise-positive effects of wearing compression tights. *Int J Sports Med* 2006; 27(5):373–378.
11. Born D-P, Sperlich B, Holmberg H-C. Bringing light into the dark: effects of compression clothing on performance and recovery. *Int J Sports Physiol Perform* 2013; 8(1):4–18.
12. Jorfeldt L, Wahren J. Leg blood flow during exercise in man. *Clin Sci* 1971; 41(5):459–473.
13. Michael JS, Dogramaci SN, Steel KA et al. What is the effect of compression garments on a balance task in female athletes? *Gait Posture* 2014; 39(2):804–809.
14. Ghai S, Driller MW, Masters RS. The influence of below-knee compression garments on knee-joint proprioception. *Gait Posture* 2016; 60:258–261.
15. Doan BK, Kwon YH, Newton RU et al. Evaluation of a lower-body compression garment. *J Sports Sci* 2003; 21(8):601–610.
16. Wannop JW, Worobets JT, Madden R et al. Influence of compression and stiffness apparel on vertical jump performance. *J Strength Cond Res* 2016; 30(4):1093–1101.
17. Kraemer JR, Bush JA, Newton RU et al. Influence of a compression garment on repetitive power output production before and after different types of muscle fatigue. *Sports Med Train Rehab* 1998; 8(2):1063–1084.
18. Ali A, Creasy RH, Edge JA. The effect of graduated compression stockings on running performance. *J Strength Cond Res* 2011; 25(5):1385–1392.
19. Bretschneider T, Koop U, Schreiner V et al. Validation of the body scanner as a measuring tool for a rapid quantification of body shape. *Skin Res Technol* 2009; 15(3):364–369.
20. Vaile J, Halson S, Gill N et al. Effect of hydrotherapy on the signs and symptoms of delayed onset muscle soreness. *Eur J Appl Physiol* 2008; 102(4):447–455.
21. Kentta G, Hassmen P. Overtraining and recovery. A conceptual model. *Sports Med* 1998; 26(1):1–16.
22. Hopkins WG. *A scale of magnitudes for effect statistics. A new view of statistics*, 1997. <http://www.sportsci.org/resource/stats/>. Accessed 1 November 2012.
23. Areces F, Salinero JJ, Abian-Vicen J et al. The use of compression stockings during a marathon competition to reduce exercise-induced muscle damage: are they really useful? *J Orthop Sports Phys Ther* 2015; 45(6):462–470.
24. Rider BC, Coughlin AM, Hew-Butler TD et al. Effect of compression stockings on physiological responses and running performance in division III collegiate cross-country runners during a maximal treadmill test. *J Strength Cond Res* 2014; 28(6):1732–1738.
25. Bovenschen HJ, Booij MT, van der Vleuten CJ. Graduated compression stockings for runners: friend, foe, or fake? *J Athl Train* 2013; 48(2):226–232.
26. Bringard A, Denis R, Belluye N et al. Effects of compression tights on calf muscle oxygenation and venous pooling during quiet resting in supine and standing positions. *J Sports Med Phys Fitness* 2006; 46(4):548–554.
27. Sear JA, Hoare TK, Scanlan AT et al. The effects of whole-body compression garments on prolonged high-intensity intermittent exercise. *J Strength Cond Res* 2010; 24(7):1901–1910.
28. Hooper DR, Dulkis LL, Secola PJ et al. Roles of an upper-body compression garment on athletic performances. *J Strength Cond Res* 2015; 29(9):2655–2660.
29. Braun WA, Dutto DJ. The effects of a single bout of downhill running and ensuing delayed onset of muscle soreness on running economy performed 48 h later. *Eur J Appl Physiol* 2003; 90(1–2):29–34.
30. Bieuzen F, Brisswalter J, Easthope C et al. Effect of wearing compression stockings on recovery after mild exercise-induced muscle damage. *Int J Sports Physiol Perform* 2014; 9(2):256–264.