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# EFFECTS OF WEARING GRADUATED COMPRESSION GARMENT DURING ECCENTRIC EXERCISE

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## Abstract

**Introduction:** Unaccustomed eccentric exercise (e.g. downhill running) causes muscle injury. We examined the effect of wearing lower body compression garment during downhill running on recovery of jump height and delayed onset muscle soreness (DOMS).

**Methods:** Young adult males (n=18, age: 20±1 yrs, height: 178±5 cm, body mass: 76.2±5.8 kg, BMI: 23.7±1.3 kg·m$^{-2}$) volunteered. Within subjects, unilateral custom fitted compression garment (9-18 mmHg) (Skins™ Sport Long Tights) was randomly assigned to be worn on the dominant or non-dominant leg. Opposite leg served as control. DOMS (scale 1-10) of vastus medialis (VM), vastus lateralis (VL) and rectus femoris (RF) muscles and vertical jump height of each leg were measured before, 0, 24, 48 and 72 hr after downhill running (5x8 min, gradient: -10%, speed: 80% of maximal running speed). Two-way repeated measures ANOVA with t-tests were used to analyse data with significance set at $P<0.05$.

**Results:** DOMS was increased compared to baseline at all time points following the downhill run for VL and VM and at 24, 48 and 72 hr for RF. The compressed leg had reduced DOMS compared to the control leg at 24 and 48 hr in RF and at 24 hr in VM. Jump height was lower than baseline in both legs at 24 hr. The compression garment had no effect on recovery of jump height. Both legs showed complete functional recovery at 48 hr.

**Conclusion:** Wearing compression garment during downhill running has no effect on functional recovery but reduces delayed onset muscle soreness in quadriceps muscles.

***Key words:*** *downhill running, compression, delayed onset muscle soreness, muscle injury, jump height*

## Introduction

Exercise with unaccustomed eccentric contractions (i.e. muscle lengthening during activation) result in immediate functional impairments, indicative of muscle injury [1, 2], and the development of muscle soreness [e.g. 3]. A whole body exercise modality in which skeletal muscle perform eccentric contractions is downhill running. Downhill running has been shown to impair muscle function with soreness to be evident for several days. The delayed onset muscle soreness (i.e. DOMS) typically peaks 2-3 days after unaccustomed eccentric contractions [4–6]. Delayed onset muscle soreness is also commonly associated with clinical observations such as pain, tenderness on palpation, swelling, and loss of range of motion.

Several treatment strategies have been implemented to help alleviate the severity of DOMS and enhance recovery of muscle function. These include non-steroid anti-inflammatory drugs [7], massage [3], ultrasound [8], cryotherapy [9], stretching [10], prior eccentric exercise [11] and compression [12].

Graduated compression garments are body-moulded garments designed to give mild compression on the skin. The compression may be beneficial to enhance recovery by improving blood flow and reducing oedema from exercise. Several studies on the effects of compression garments have shown improved performance and recovery after exercise-induced muscle damage [13–15]. In these studies, the compression garments were worn during the recovery phase. However, physiological causes for the development of exercise-induced muscle damage (e.g. DOMS) may be attenuated by wearing graduated compression garments during exercise. Although the specific mechanism(s) for the development of delayed onset muscle soreness are not known, muscle soreness was reduced following a 10 km road race with participants wearing graduated compression stockings during the exercise and not during recovery [16]. It is possible that wearing compression garments during eccentric exercise may limit the amount of active fibre lengthening that leads to injury, reducing the inflammatory response that may contribute to delayed onset muscle soreness. Studies on the effects of wearing graduated compression garments during eccentric exercise-induced muscle injury on subsequent recovery are lacking.

Therefore, the purpose of this study was to examine the effects of a lower limb graduated compression garment worn during downhill running on subsequent perceived ratings of DOMS and single leg vertical jump performance during recovery. It was hypothesised that compression garments during eccentric exercise would reduce DOMS and functional deficits.

## Methods

### *Participants*

The study was approved by the University of Chichester Ethical Committee and was carried out in accordance with the Declaration of Helsinki. Eighteen healthy male students from the University of Chichester's 1st and 2nd football team volunteered for the study. Their average age, height, body mass and BMI (means±SD) were 20.3±0.8 yrs, 1.78±0.05 m, 76.2±5.8 kg and 23.7±1.3 kg·m$^{-2}$, respectively. None of the subjects had any involvement in physical activity or exercise that involved unaccustomed eccentric muscle contractions over the past six months. Subjects were advised not to change dietary habits and avoid unaccustomed activity during the testing period. Subjects provided written informed consent before testing began.

### *Compression Garment*

The garments used for this study were commercially available lower limb compression tights (Skins™ Sport Long Tights, Skins Compression Garments, Sydney, Australia – 76% Nylon Tactel Microfibre, 24% Elastane Creora). Height and body mass of each subject were supplied to the manufacturer to ensure custom-fit sizes were worn by the participants. The garment covered the lower limb of one leg only from the superior aspect of the medial malleolus of the ankle to the superior aspect of the iliac crest. This experimental approach avoided the repeated bout effect on injury markers after eccentric exercise. The compression garments used had an average compression rate of 18mmHg at the calf and 9mmHg at the thigh (E. Hames. Skins™, personal communication). The leg wearing the compression garment was randomly assigned with the opposite leg acting as the control. Note that studies examining effects of compression garment may differ by using other commercially available garments with different pressures [e.g. 17].

### *Maximum running velocity*

During the preliminary session, participants performed an incremental running treadmill test to determine maximum running velocity on a HP Cosmos Pulsar treadmill (Bodycare Products. Southam, Warwicks, UK). The compression garment was not worn during this test. Following a 5 minute warm-up run and general stretching, participants began exercising at a speed of 10 km·h$^{-1}$ at a 0% gradient. The treadmill speed increased by 1 km·h$^{-1}$ every minute until volitional exhaustion [18]. Maximum treadmill running velocity was taken as the highest speed (km·h$^{-1}$) maintained for a complete minute during the incremental running treadmill test. When a participant was unable to complete 60 seconds at a particular treadmill velocity, running velocity of the preceding completed minute was taken as the peak treadmill running velocity. Maximum running velocity was 17.8±1.3 km·h$^{-1}$ (range: 15-20 km·h$^{-1}$). 80% of the maximum running velocity was used for downhill running.

### *Downhill running*

Compression garments were only worn during the downhill running protocol. The downhill running protocol, previously shown to be successful in inducing DOMS [19], consisted of 1 session where, following a 5 minute warm up at 0% gradient and 4 km·h$^{-1}$, each participant underwent 5 x 8 minute bouts of downhill running performed at 80% of $\dot{V}O_2$max at a -10% gradient. Two minute static recoveries followed each bout. A safety harness was attached to the participant throughout the duration of the session. During the downhill run, heart rate (Polar Electro UK Ltd, Warwick, UK) was measured in the final minute of each bout. Heart rates values were 148±20 (bout 1), 160±18 (bout 2), 166±18 (bout 3), 170±18 (bout 4), and 172±18 (bout 5).

### *Delayed onset muscle soreness*

Delayed onset muscle soreness was evaluated before and immediately after testing and again at 24, 48 and 72 hr following the downhill running session. A leg blood pressure cuff (Omron, automatic blood pressure cuff, Medistore, UK) was wrapped around a golf ball [adapted from 20] and placed on the *m. rectus femoris, m. vastus medialis* or *m. vastus lateralis*. Location of the golf ball was based on location of EMG electrode placements on muscles of interest [21]. A standard pressure of 100 mmHg was applied. When a pressure of 100 mmHg was reached, the subjects indicated the intensity of DOMS on a 1-10 point Visual Analogue Scale (VAS) with 1 representing no soreness and 10 indicating extreme soreness.

### *Single Leg Vertical Jump*

A single leg vertical jump was performed on each leg before the downhill run and then at the same time intervals as muscle soreness measurements. Three SLVJ's were performed on each leg with a 30 second recovery period between each effort. All participants were familiarised with one-legged jumping tests. Participants were instructed to step onto a jump mat, place their hands on their hips, squat to 90 degrees on a single leg, jump as high as possible, and then landing on two feet. Flight time was recorded for the three jumps. The average flight time was used to calculate vertical jump height. Our experimental design allowed the compression garment to be worn on one leg only during eccentric exercise. Because compression garments by athletes are worn due to a potential performance benefit and/or improved recovery from exercise, a single leg vertical jump was chosen as a performance measurement as this would be more applicable to a sporting environment compared to a physiological measurement such as maximal voluntary isometric force.

***Data Analysis***

Statistical analyses were computed using SPSS for Windows version 16.0 Statistical Software Package (SPSS Inc., Chicago, IL). Data are presented as means±SD and were initially examined both visually and statistically for normal distribution. Two-way repeated measures analysis of variance (ANOVA) was used. Significance was set at $P<0.05$. The Mauchly sphericity test was used to test for assumptions of homogeneity of variance. Where this was violated, the Greenhouse-Geisser value was used to adjust degrees of freedom to increase the critical value of the $F$ ratio. If any differences were found, pre-planned t-tests were used to analyse for compression effects at similar time point or time effects for compressed and non-compressed leg. It should be noted that data for delayed onset muscle soreness (measured on a 10 point scale) cannot be normally distributed. However, design of the experiment does not allow non-parametric comparison. Therefore, a two-way repeated measures ANOVA was used and it was accepted that one of the assumptions of ANOVA was violated.

**Results**

***Delayed onset muscle soreness***

Delayed onset muscle soreness increased significantly over time following the downhill running protocol (Fig. 1-3). The results of the ANOVAs for each muscle group were VM ($F_{(4,68)}=16.102$, $P<0.01$), VL ($F_{(4,68)}=15.966$, $P<0.01$) and RF ($F_{(4,68)}=24.804$, $P<0.01$). For VL, delayed onset muscle soreness values were higher compared to baseline at all time points for both compressed and non-compressed leg ($P<0.01$) with no effect for compression or interaction (Fig. 1).

For RF, there was no change in ratings of delayed onset muscle soreness immediately post-exercise for the compressed leg. Compared to baseline, the delayed

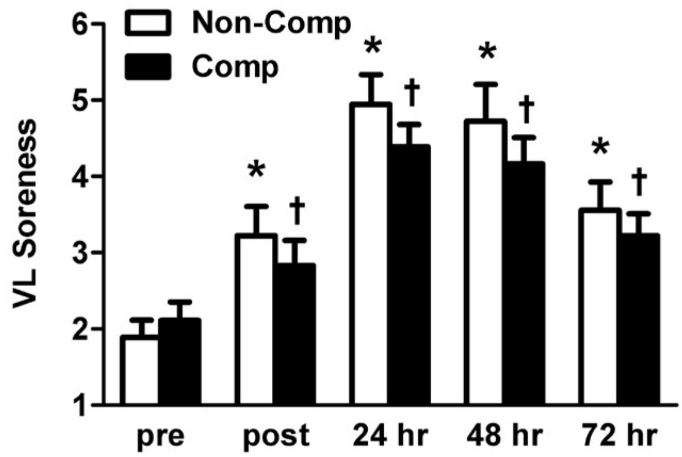


Fig. 1. *Delayed onset muscle soreness of vastus lateralis (VL) muscle prior to and 0, 24, 48 and 72 hr following downhill running. *, indicates significant difference from pre-value (P<0.05); †, indicates significant difference from pre-value (P<0.05). Non-Comp, non-compressed leg; Comp, compressed leg.*

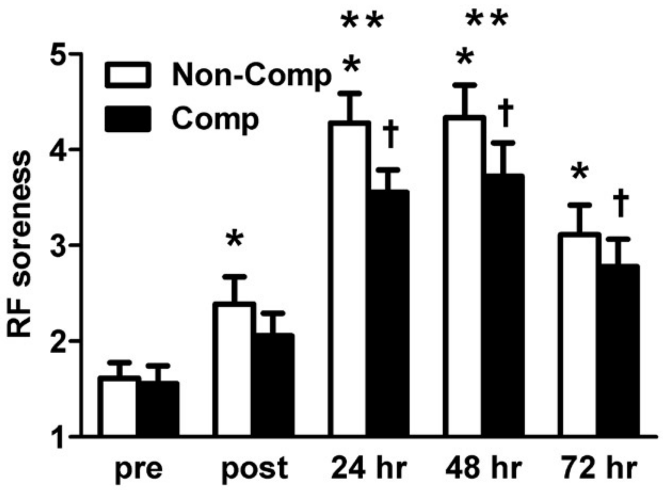


Fig. 2. *Delayed onset muscle soreness of rectus femoris (RF) muscle prior to and 0, 24, 48 and 72 hr following downhill running. *, indicates significant difference from pre-value (P<0.05); †, indicates significant difference from pre-value (P<0.05); **, indicates significant difference between non-compressed and compressed leg (P<0.05). Non-Comp, non-compressed leg; Comp, compressed leg.*

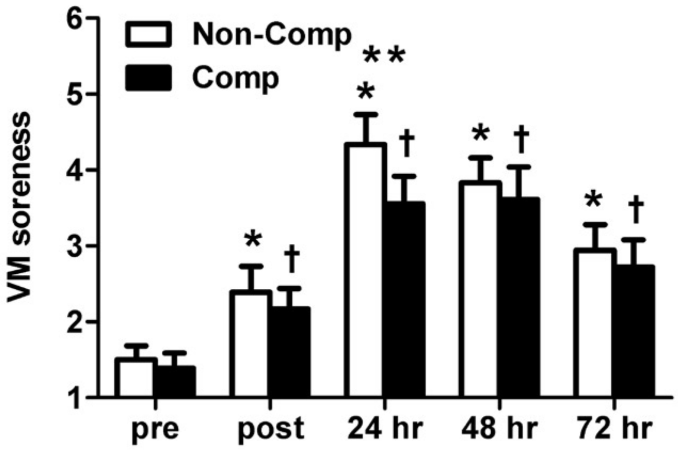


Fig. 3. *Delayed onset muscle soreness of vastus medialis (VM) muscle prior to and 0, 24, 48 and 72 hr following downhill running. *, indicates significant difference from pre-value (P<0.05); †, indicates significant difference from pre-value (P<0.05); **, indicates significant difference between non-compressed and compressed leg (P<0.05). Non-Comp, non-compressed leg; Comp, compressed leg.*

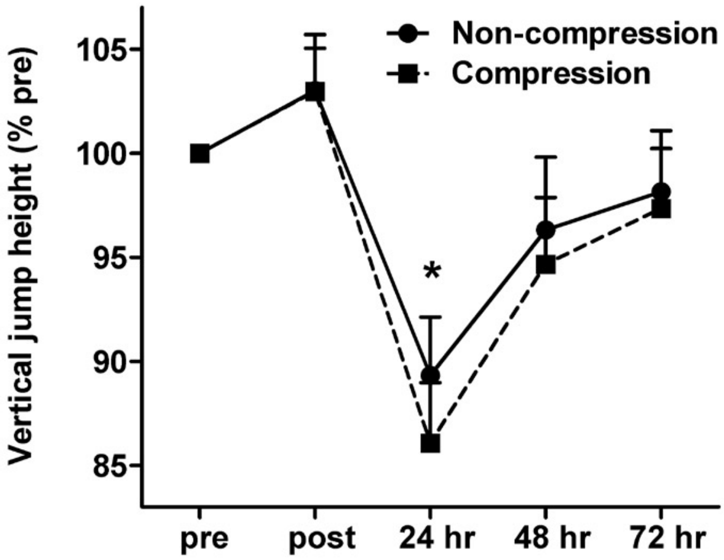


Fig. 4. *Changes in one-legged vertical jump height as a percentage of pre-value at 0, 24, 48 and 72hr following downhill running. *, indicates significant difference from pre-value (P<0.05).*

onset muscle soreness in RF of both compressed and non-compressed was higher at 24, 48 and 72 hr. RF of compressed leg had lower values of delayed onset muscle soreness at 24 hr ($P<0.01$) and 48 hr ($P<0.05$) (Fig. 2).

For RF, there was no interaction effect. For VM, delayed onset muscle soreness values were higher compared to baseline at all time points for both compressed and non-compressed leg ($P<0.01$) with no interaction effect (Fig. 3). VM of compressed leg had lower values of delayed onset muscle soreness at 24 hr ($P<0.05$).

***Single Leg Vertical Jump***

A significant main effect of time was observed on SLVJ relative to baseline ($F_{(4,68)}=10.868$, $P<0.01$). There was a significant decline in vertical jump height in both legs at 24 hr ($P<0.01$). There was no effect of compression or interaction effect. Both legs had complete recovery at 48 hr (Fig. 4).

**Discussion**

The main finding of the study was that wearing a graduated compression garment during eccentric exercise did not enhance functional recovery but was associated with lower values for delayed onset muscle soreness. As far as we know, this is the first study that examined the effect of wearing a graduated compression garment during an eccentric exercise-induced muscle injury protocol. Only one study examined muscle soreness following exercise (i.e. 10 km road race) with participants wearing graduated compression stockings during the exercise and not during recovery [16]. Similar to our study, wearing graduated compression garments reduced levels of soreness in upper leg after 24 hr [16]. In that study, there was a trend of wearing compression stockings on running time, a potential confounding variable that was avoided in our study. In our study, both legs were tested as the result of one downhill run. Our experimental design did not take into account potential differences for susceptibility of dominant and non-dominant legs for eccentric-contraction induced muscle injury.

Most studies that have examined the effects of graduated compression garments had subjects wearing those during the recovery phase. Beneficial effects of wearing graduated compression garments during recovery have been reported. For example, Jakeman et al. [13] reported reduced soreness in the compressed leg from plyometric jumping exercises. Decreased perceptions of soreness at 72 and 96 hr post eccentrically induced muscle damage were reported in upper extremity muscles [14, 22]. Davies et al [23] reported reductions in perceived muscle soreness 48 hr after maximal drop jumps. We have no evidence that the mechanism(s) causing muscle soreness were influenced by wearing the compression. It is likely that unaccustomed eccentric contractions overstretched sarcomeres, ultimately leading to an inflammatory response, i.e. oedema formation, due to the breakdown of muscle fibres and membrane damage. In addition, it is likely that the delayed onset muscle soreness resulted from the chemical stimulation of the sensory nerve endings of the involved muscular structures from the swelling and osmotic pressure in the muscle. It is tempting to speculate that wearing the graduate compression garments during eccentric-exercise induced muscle injury may have reduced the potential to develop oedema and leading to decreased perceptions of soreness. The reduced oxygen demand during running with compression garments [24] may implicate for our study that there could have been a reduced muscle oxygen demand in the compressed leg leading to diminished oxidative free radical activity and reduced soreness (see [25] for a potential role of free radicals in DOMS). However, the nature of our experimental protocol complicates interpretation. In addition, we feel that the absence of exact compression values at location of DOMS measurements does not allow statements on potential muscle-specific effects of compression garments and further research is required. Positive results for the compressed leg with respect to delayed onset muscle soreness maybe due to the Hawthorne effect [26], i.e. positive results result due to the known potentially beneficial treatment effect. Future studies may want to use graduated compression garments with severely less compression to examine the Hawthorne effect. However, it is possible that wearing graduated compression garments during eccentric exercise may have influenced the damaging effect of eccentric contractions and reduced the impact of events that may lead to delayed onset muscle soreness such as the inflammatory response. Mechanical support afforded by compressive clothing may also have promoted stable alignment of muscle fibres [22]. Doan et al. [27] also propose that a reduction in oscillatory displacement of the muscle may occur potentially reducing the damaging effect of the eccentric contractions during downhill running. It is known that performance during some events may be enhanced by wearing graduated compression garments indicating an effect on muscle functioning during exercise.

We were surprised that the downhill run did not result in a change in vertical jump height immediately after exercise, a finding potentially in conflict with the reported immediate effects on force producing capability of skeletal muscles after eccentric exercise. This finding may be explained by the level of sport participation within the current sample. All participants were highly experienced football players tested in season. Football players are familiar with the performance of jumping movements in fatigued conditions. Minor muscle fatigue and/or injury may not necessarily influence jumping performance due to a change in segmental coordination [28]. The significant drop in vertical jump height at 24 hr following damaging exercise for both legs is consistent with previous research [13] but there was no effect of compression on recovery of jump height.

In conclusion, it was demonstrated that wearing graduated compression garments during eccentric exercise reduced levels of delayed onset muscle soreness but had no effect on performance deficits during recovery.

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**References**

1. Warren GL, Lowe DA, Armstrong RB. Measurement tools used in the study of eccentric contraction-induced injury. *Sports Med* 1999; 27: 43-59. doi: 10.2165/00007256-199927010-00004.
2. Willems MET, Northcott SR. Gender differences after downhill running for voluntary isometric contractions of knee extensor muscles using surface EMG. *Med Sport* 2009; 13: 35-42. doi: 10.2478/v10036-009-0007-4.
3. Willems MET, Hale T, Wilkinson CS. Effects of manual massage on muscle-specific soreness and single leg jump performance after downhill treadmill walking. *Med Sport* 2009; 13: 61-6. doi: 10.2478/v10036-009-0011-8.
4. Clarkson PM, Brynes WC, McCormick KM et al. Muscle soreness and serum creatine kinase activity following isometric, eccentric and concentric exercise. *Int J Sports Med* 1986; 7: 152-6. doi: 10.1055/s-2008-1025753.
5. Clarkson PM, Nosaka K, Braun B. Muscle function after exercise-induced muscle damage and rapid adaptation. *Med Sci Sports Exerc* 1992; 24: 512-20.

6. Nosaka K, Clarkson PM, McGuiggan M et al. Time course of muscle adaptation after high-force eccentric exercise. *Eur J Appl Physiol* 1991; 63: 70-6.
7. Donnelly AE, Maughan RJ, Whiting PH (2000). Effects of ibuprofen on exercise-induced muscle soreness and indices of muscle damage. *Br J Sports Med* 2000; 24: 191-5. doi:10.1136/bjsm.24.3.191.
8. Ciccone CD, Leggin BG, Callamaro JJ. Effects of ultrasound and trolamine salicylate phonopheresis on delayed onset muscle soreness. *Phys Ther* 1991; 71: 666-78.
9. Paddon-Jones DJ, Quigley BM. Effect of cryotherapy on muscle soreness and strength following eccentric exercise. *Int J Sports Med* 1997; 18: 588-93. doi: 10.1055/s-2007-972686.
10. Johansson PH, Lindström L, Sundelin G et al. The effects of pre-exercise stretching on muscular soreness, tenderness and force loss following heavy eccentric exercise. *Scand J Med Sci Sports* 2007; 9: 219-25. doi: 10.1111/j.1600-0838.1999.tb00237.x.
11. Cleary MA, Kimura IF, Sitler MR et al. Temporal pattern of the repeated bout effect of eccentric exercise on delayed-onset muscle soreness. *J Athl Train* 2002; 37: 32-6.
12. Duffield R, Portus M. Comparison of three types of full-body compression garments on throwing and repeated-sprint performance in cricket players. *Br J Sports Med* 2007; 41: 409-14. doi:10.1136/bjsm.2006.033753.
13. Jakeman JR, Byrne C, Eston RG (2010). Lower limb compression garment improves recovery from exercise-induced muscle damage in young, active females. *Eur J Appl Physiol* 2010; 109: 1137-44. doi: 10.1007/s00421-010-1464-0.
14. Kraemer WJ, Bush JA, Wickham RB et al. Influence of compression therapy on symptoms following soft tissue injury from maximal eccentric exercise. *J Orthop Sports Phys Ther* 2001; 31: 282-90.
15. Trenell MI, Rooney KB, Sue CM et al. Compression garments and recovery from eccentric exercise: a $^{31}$P-MRS study. *J Sports Sci Med* 2006; 5: 106-14.
16. Ali A, Caine MP, Snow BG. Graduated compression stockings: Physiological and perceptual responses during and after exercise. *J Sports Sci* 2007; 25: 413-9. doi: 10.1080/02640410600718376.
17. Scanlan AT, Dascombe BJ, Reaburn PR et al. The effects of wearing lower-body compression garments during endurance cycling. *Int J Sports Physiol Perform* 2008; 3: 424-38.
18. Noakes TD, Myburgh KH, Schall R. Peak treadmill running velocity during the $VO_2$max test predicts running performance. *J Sports Sci* 1990; 8: 35-5.
19. Eston RG, Finney S, Baker S et al. Muscle tenderness and peak torque changes after downhill running following a prior bout of isokinetic eccentric exercise. *J Sports Sci* 1996; 14: 291-9.
20. Carter A, Dodbrigde J, Hackney AC. Influence of estrogen markers on muscle tissue damage following eccentric exercise. *Fiziol Cheloveka* 2001; 27: 626-30.
21. Hermens HJ, Freriks B, Disselhorst-Klug C et al. Development of recommendations for SEMG sensors and sensor placement procedures. *J Electromyogr Kinesiol* 2000; 10: 361-74. doi:10.1016/S1050-6411(00)00027-4.
22. Kraemer 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.
23. Davies V, Thompson KG, Cooper SM. The effects of compression garments on recovery. *J Strength Cond Res* 2009; 23: 1786-94. doi:10.1016/j.jsams.2008.10.006.
24. 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: 373-8. doi: 10.1055/s-2005-865718.
25. Close GL, Ashton T, McArdle A et al. The emerging role of free radicals in delayed onset muscle soreness and contraction-induced muscle injury. *Comp Biochem Physiol A Mol Integr Physiol* 2005; 142: 257-66.
26. Parsons HM. What Happened at Hawthorne?: New evidence suggests the Hawthorne effect resulted from operant reinforcement contingencies. *Science* 1974; 183(4128): 922-32.
27. Doan BK, Kwon Y, Newton RU et al. Evaluation of a lower-body compression garment. *J Sports Sci* 2003; **21,** 601-10. doi: 10.1080/0264041031000101971.
28. Rodacki AL, Fowler NE, Bennett SJ. Multi-segment coordination: Fatigue effects. *Med Sci Sports Exerc* 2002; **33:** 1157-67.

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