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RESEARCH ARTICLE

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The effects of lower-body compression garments on recovery between exercise bouts in highly-trained cyclists

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Abstract

The use of compression garments as a recovery strategy has become popular amongst athletes. The aim of the current study was to investigate the effect of lower-body compression garments on recovery between two cycling bouts. Ten highly-trained cyclists (mean ± SD; age = 31 ± 6 years; height = 181 ± 6 cm; mass = 75.9 ± 5.9 kg; VO_{2peak} = 66.6 ± 3.8 $mL.kg.^{-1}min.^{-1}$) performed two 30-minute cycling bouts (15-minutes at a fixed power output, 15-minute time-trial) on a cycle ergometer, separated by a 60-minute passive recovery period where either lower-body compression garments (LBCG) or loose-fitting shorts (CON) were worn. Subject's performed both trials in a randomized, crossover design separated by three days. Blood lactate, leg girths and perceived soreness was measured throughout the recovery period. Results indicated a small but significant improvement ($P < 0.05$) in recovery as evidenced by the maintenance of power output in the second exercise bout in the LBCG trial when compared to the CON trial (-0.20% and -2.15%, respectively. Effect Size (ES); 0.22). LBCG were also associated with significant reductions in limb girths and blood lactate concentration when compared to CON. While not statistically significant, there was a moderate effect on perceived soreness in the LBCG trial (ES; -0.62). We would suggest that lower-body compression garments enhance recovery between cycling bouts and improve subsequent performance.

Keywords: performance, blood lactate, cycling, fatigue, time-trial

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Introduction

The use of compression garments and compression bandaging has been well documented in the medical literature as a method of treating circulatory and lymphatic disorders (Ramelet 2002). Given the efficacy of compression garments as a treatment in the medical field, the use of compression garments in the athletic industry has become increasingly popular over the past decade, with several commercial companies claiming that the associated medical benefits can be applied to enhance recovery in an exercise setting.

Compression garments are thought to improve venous return through application of graduated compression to the limbs from proximal to distal (Benkö et al. 2001; Bochmann et al. 2005; Lawrence and Kakkar 1980). Compression garments exert pressure directly on underlying tissues which is proposed to reduce the transmural pressure of arterioles, causing them to dilate and subsequently, increase blood-flow (Davies et al. 2009; O'Donnell Jr et al. 1979). The garments are also thought to result in a redistribution of blood from the periphery to the deep venous system, further aiding in an increase in the return of blood flow to the heart (Partsch and Mosti 2008). The promotion of venous return following exercise is thought to be an effective method in removing the metabolic waste products that accumulate during exercise, and therefore, enhance recovery (Davies et al. 2009). Furthermore, the external pressure created by compression garments may reduce the intramuscular space available for swelling, attenuating the inflammatory response and reducing muscle soreness (Bochmann et al. 2005; Davies et al. 2009; Kraemer et al. 2001a).

Research findings into the effects of compression garments on recovery from exercise remain equivocal. While some studies have reported benefits to improved force production, countermovement and squat jump performance and decreased perceptions of muscle soreness following the use of compression garments for recovery (Jakeman et al. 2010; Kraemer et al. 2001a; Kraemer et al. 2001b; Kraemer et al. 2010), others have also found no beneficial effect on indices of strength, speed and explosive performance (Carling et al. 1995; Duffield et al. 2008; Duffield and Portus 2007; French et al. 2008). While there are studies that both support and refute any benefits of compression garments, there are no studies in the literature that have reported detrimental effects on recovery between exercise bouts when compared to a passive control. The majority of the compression garment research in the sport setting has investigated the effects of compression garments on

recovery following anaerobic or explosive type exercise, with very little focus on more aerobic time-trial type efforts (De Glanville and Hamlin 2012).
There has only been two studies that have investigated the effect of compression garments on recovery between two cycling bouts, both reporting positive benefits to subsequent performance (Chatard et al. 2004; De Glanville and Hamlin 2012). In the De Glanville and Hamlin (2012) study, subjects were required to wear compression garments for 24 hours between exercise bouts (40-km time-trials). The results showed a higher mean power in the compression group when compared to the placebo in the second time-trial (3.3 ±1.1%, mean ±90% confidence interval), with a trivial and unclear effect on oxygen cost and rating of perceived exertion, respectively. Chatard et al. (2004) investigated the use of compression garments for 80-minutes between two five-minute performance trials in moderately-trained, elderly subjects. The compression garment trial resulted in a significantly better maintenance of performance in the second five-minute cycling bout when compared to the control (2.1 ± 1.4%). This performance benefit was associated with significantly decreased blood lactate concentration and haematocrit during the recovery period in the compression garment group when compared to the control (F = 7.7 and 6.8 respectively, P < 0.01). However, De Glanville & Hamlin (2012) studied multisport athletes and Chatard et al. (2004) studied trained elderly (> 60 years) cyclists, suggesting that both of these studies examined the recovery between cycling bouts, in older or non-cycling specific populations. Whether the same effects would be seen in highly-trained, younger cyclists remains somewhat unknown.
Therefore, the aim of the current study was to evaluate the effect of wearing compression garments (during 60-minutes of passive recovery between two 30-minute exercise bouts) on a number of physiological and perceptual markers and subsequent cycling performance. Furthermore, the study aimed to be the first to investigate the effect of compression garments on short-term recovery in a highly-trained cycling population.

Materials and methods

Participants

Ten highly-trained cyclists (mean ± SD; age = 31 ± 6 years; height = 181 ± 6 cm; mass = 75.9 ± 5.9 kg; VO_{2peak} = 66.6 ± 3.8 mL.kg.$^{-1}$min.$^{-1}$) volunteered to take part in the current study. All testing took place during the competition phase of the cycling season in Australia where all subjects were racing at either A or B grade level in their State. Subjects were required to give informed consent prior to any testing. The study was approved by the Australian Institute of Sport Research Ethics Committee and was conducted in accordance with the international standards required by the Journal of Science and Cycling (Harriss and Atkinson 2011).

Design

The current study consisted of five separate testing sessions over a three week period. Initially, subjects completed an incremental cycling test on an electromagnetically braked cycle ergometer (Lode Excalibur Sport, Groningen, Netherlands) to establish each individual's peak aerobic power output (PPO) and VO_{2peak}. Following the incremental cycling test, subjects completed two familiarization trials of the exercise sessions in an attempt to minimize any learning effect. Two separate experimental trials were then performed in a randomized, crossover design separated by 3 (±1) days. In order to control any dietary variables, subjects completed a 24-hour food diary prior to their first trial and were instructed to replicate their diet as closely as possible before the second trial. Training was also controlled for, with subjects standardizing all training 72 hours before testing on both occasions. Subjects were asked to refrain from strenuous exercise (<24 h) and caffeine (<12 h) and to arrive at each session in a fully rested, hydrated state. All testing was performed at the same time of day (± 1 h) to minimize diurnal variation, and tests were always performed on the same cycle ergometer (Lode Excalibur Sport, Groningen, Netherlands).

Procedures

Incremental exercise test

Prior to the start of the study, the cycle ergometer (Lode Excalibur Sport, Groningen, Netherlands) was calibrated on a dynamic calibration rig using a first principles approach by specialists at the Australian Institute of Sport (Gardner et al. 2004). The incremental cycling test started at 150 watts and increased in power output by 25 watts every minute until volitional exhaustion. Oxygen consumption was measured throughout the progressive exercise test using a metabolic analyzer (Australian Institute of Sport, Canberra, Australia). Peak Power Output was determined using the following formula:

$$PPO = W_{com} + (t/60 \times 25)$$

Where W_{com} is the power output for the last full workload completed, t is the time in seconds that the final uncompleted workload was sustained, 60 is the target number of seconds in each workload and 25 is the workload increment in watts.

Exercise tasks

Each experimental trial involved subjects performing two identical exercise bouts separated by a 60-minute recovery period. The identical cycle exercise bouts (E1 and E2) consisted of a 10 minute warm-up period (two minutes at each of the following intensities: 125W, 150W, 175W, 200W, 70% PPO), 15 minutes at a workload equal to 70% PPO followed immediately by a 15 minute time-trial. The exercise protocol used in the current study was adapted from previous studies (Jeukendrup et al. 1996; Vaile et al. 2008), and was used to simulate sporting events where this length of recovery time is common (e.g. track cycling events like the keirin, sprint and omnium). As demonstrated in a previous study conducted in our laboratory (Driller 2012), the typical error of measurement for total work completed during this exercise protocol is approximately 1.3%. Subjects had access to time information and were required to produce as much work as possible in the timeframe, but no other information was provided. During exercise and recovery, a carbohydrate beverage (Gatorade; 6% carbohydrate content) was supplied to subjects and they were instructed to drink ad-libitum. The volume of fluid consumed and the time-points in which it was consumed were recorded in order to be replicated in the subsequent trial.

Immediately following E1, a standardized active recovery protocol was completed (five minutes at 40% PPO) followed by a 60-minute period of passive recovery either wearing lower-body compression garments (LBCG) or loose-fitting shorts (CON). Passive recovery consisted of the subject remaining seated in a semi-reclined position in a temperature-controlled environment (20.7 ± 0.3 °C). One hour after the cessation of E1, subjects were required to repeat the initial exercise bout (E2).

Compression Garments

The LBCGs used in the current study were men's full-length tights (2XU Elite Compression Tights, Victoria, Australia), which comprised of 50 and 70 denier LYCRA® fibre material. The LBCG ran from the superior aspect of the medial malleolus of the ankle to fractionally superior to the iliac crest. Each LBCG was fit according to manufacturer's guidelines using each subject's stature and body mass. While not measured in the current study, according to unpublished observations taken on >50 athletes in our laboratory, the LBCG's exert a graduated compression with a pressure of approximately 20.5 ± 3.1 mmHg at the calf decreasing to 11.8 ± 2.6 mmHg at the mid-thigh. During the control trial, subjects wore loose-fitting running shorts in the recovery period to ensure there were no possible compression benefits associated with the clothing worn. During the exercise tasks for both trials, subjects wore the same pair of above-knee cycling shorts.

Blood lactate

Blood lactate concentration was measured via a capillary finger-tip sample and was analyzed with a Lactate-Pro analyzer (Arkray, Shiga, Japan). Prior to each sample, the finger was cleaned using an alcohol wipe and then punctured using a single-use lancet. The first drop of blood was then discarded before a blood sample was taken for analysis. The test-retest reliability of the Lactate Pro has been previously reported, with technical error of measurement results ranging from 0.1-0.4 $mmol.L^{-1}$ at blood lactate concentrations of 1-18 $mmol.L^{-1}$ (Tanner et al. 2010). Blood lactate concentration was analyzed at 0, 10, 30 and 60 minutes throughout the recovery period.

Perceptual scale

Subjects were required to give ratings of their perceived leg muscle soreness on a scale of one (no soreness) to ten (very sore) (Thompson et al. 1999). Ratings were provided while subjects contracted their leg muscles in the half-squat position. Perceived soreness (PS) ratings were recorded immediately pre and post E1, at 10, 30 and 60 minutes during recovery.

Limb circumferences

A non-stretch anthropometric measuring tape (Lufkin Executive Thinline, TX, USA) was used to measure the circumference of the upper and lower leg. On the lower-leg, the landmark used was at the widest girth of the calf muscle. The landmark on the upper-leg used in the current study was the midpoint between the inguinal fold and the posterior superior border of the patella (Howatson et al. 2009). Measurement sites were marked with a permanent marker to ensure retest reliability and measurements were taken at 0 and 60 minutes during the recovery period.

Statistical analyses

Simple group statistics are shown as means ± between-subject standard deviations. Mean effects of training and their 90% confidence limits were estimated with a spreadsheet via the unequal variances t statistic computed for change scores between pre- and post-tests in the two groups. Each subject's change score was expressed as a percentage of baseline score via analysis of log-transformed values, to reduce bias arising from non-uniformity of error. Perceived soreness was analyzed without log-transformation. Standardized changes in the mean of each measure were used to assess magnitudes of effects and provide the likelihood of the true effects being practically positive, trivial and negative by dividing the changes by the smallest worthwhile change (Batterham and Hopkins 2006). As identified in our laboratory, the smallest worthwhile change for the performance test was deemed to be 1.3% (Driller 2012). Differences between groups at baseline were controlled for by using the baseline values as the covariate in the analysis. Magnitudes of the standardized effects were interpreted using thresholds of 0.2, 0.6, 1.2 and > 2.0 for small, moderate, large and very large, respectively (Hopkins 1997). An effect size of 0.2 was considered the smallest worthwhile positive effect. The effect was deemed unclear if its confidence interval overlapped the thresholds for small positive and negative effects. Statistical significance was set at $P \leq 0.05$ for all analyses.

Results

There was no significant difference between groups in mean power output for E1 ($P = 0.23$). There was a significant improvement ($P < 0.05$) in recovery as evidenced by the maintenance of power output in the second exercise bout in the LBCG trial when compared to the CON trial (-0.20% and -2.15%, respectively – Figure 1). This maintenance of power output was associated with a small effect size (ES; 0.21) and a

Table 1. Mean (± SD) values for the two exercise bouts (E1 and E2) and for the measured variables pre- and post- the 60-minute passive recovery period for the lower-body compression garment (LBCG) and control (CON) trials.

	LBCG	CON	Δ LBCG - Δ CON (% ±90% Confidence Limits and Effect Size)	Likelihood (%) of LBCG being positive/trivial/negative (Compared to CON)
E1 (Watts)	312.1 ± 23.3	314.9 ± 28.8	1.8 ±1.3* Small	76/24/0
E2 (Watts)	311.5 ± 25.5	308.1 ± 24.4		
Pre-recovery PS	7.4 ± 1.9	6.5 ± 2.4	-1.1 ±1.2 Moderate	81/17/2
Post-recovery PS	1.9 ± 1.5	3.2 ± 2.5		
Pre-recovery TG	54.0 ± 3.6	53.8 ± 3.5	-0.9 ±0.6* Trivial	88/12/0
Post-recovery TG	52.9 ± 3.6	53.2 ± 3.2		
Pre-recovery CG	37.6 ± 2.0	37.8 ± 1.8	-1.0 ±0.7* Trivial	89/11/0
Post-recovery CG	37.1 ± 2.0	37.6 ± 2.0		
Pre-recovery La	9.5 ± 2.3	11.0 ± 2.2	-26.1.1 ±17.9* Moderate	100/0/0
Post-recovery La	3.0 ± 1.0	4.0 ± 1.1		

There was no significant difference between trials for power output at E1. PS = Perceived soreness; TG = Thigh girth; CG = Calf girth; La = Blood lactate concentration
* = Significant difference ($P < 0.05$).

76% practical likelihood of LBCG being a positive recovery strategy when compared to CON (Table 1).

Discussion

Our findings suggest that relative to a control garment (loose-fitting shorts), wearing lower-body compression garments for a 60-minute passive recovery period between successive 30-minute exercise tasks (15-minute at a fixed power output, 15-minute time-trial) significantly improved subsequent aerobic performance. This is the first study to show improvements in recovery between two endurance cycling bouts when using compression garments as a short-term (60-minute) recovery strategy in highly-trained cyclists.

The present study supports previous literature examining the effects of compression garments as a recovery aid (Chatard et al. 2004; De Glanville and Hamlin 2012; Jakeman et al. 2010; Kraemer et al. 2001a; Kraemer et al. 2010). The present study resulted in a similar magnitude of improvement when compared to two other studies investigating the use of compression garments during recovery between two cycling bouts (Chatard et al. 2004; De Glanville and Hamlin 2012). These previous studies reported a 2.1% and a 3.3% improvement in the compression garment trial (compared to control) when wearing the garments for 80 minutes and 24 hours between bouts, respectively. Similarly, the current study resulted in a 1.8 ±1.3% (mean ± 90% confidence limits) improvement in the compression garment trial when compared to the control. This improvement in performance represents a 76% likelihood of a positive effect (with 0% likelihood of a negative effect) on performance when wearing compression garments during recovery between two cycling bouts, as assessed by magnitude based inferences (Batterham and Hopkins 2006). A novel aspect of the current study was that we were able to show improved recovery in highly-trained athletes where a short turnaround time between exercise bouts was required. The application of these findings may be relevant to events where this length of recovery time is common (e.g. track cycling events like the keirin, sprint and omnium).

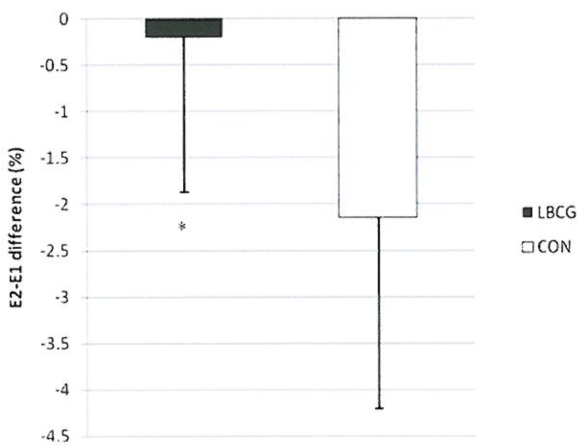

Figure 1. Mean percentage decrement in performance (Watts) between the two exercise bouts for both the lower-body compression garment (LBCG) and control (CON) trials (-0.20% and -2.15% respectively). Error bars represent standard deviations. * Significant difference between LBCG and CON.

Mechanisms associated with improved recovery from exercise when wearing compression garments remain unclear (MacRae et al. 2011). It has been suggested that wearing graduated compression garments acts to increase venous blood flow, thereby enhancing stroke volume and cardiac output (Chatard et al. 2004). This increase in stroke volume and cardiac output may enhance muscle blood flow and oxidation, thereby aiding in the removal of metabolic waste that accumulates during high-intensity exercise. While blood flow was not measured in the current study, we did measure blood lactate concentration during the recovery period, which can indirectly reflect changes in venous return (Mayberry et al. 1991). The current study confirmed the results of Chatard et al. (2004) who indicated that wearing compression stockings following an exhaustive exercise bout decreases blood lactate levels to a greater extent than a control condition during a 30-60 minute recovery period. The current study showed a significant decrease in blood lactate concentration when wearing compression garments from pre- to post- recovery (9.5 ± 2.3 to 3.0 ± 1.0 $mmol.L^{-1}$). This decrease in blood lactate during the recovery period resulted in a 100% likelihood that wearing compression garments was a more effective method to enhance blood lactate removal when compared to not wearing compression garments (control trial).

It has been suggested that the external pressure created by compression garments may reduce the intramuscular space available for swelling and promote stable alignment of muscle fibres, attenuating the inflammatory response and reducing muscle soreness (Bochmann et al. 2005; Davies et al. 2009; Kraemer et al. 2001a). The current study would support this theory as identified by the significant reduction in both thigh and calf girth measurements following the recovery period in the LBCG trial compared to the CON trial (Table 1). While the changes in perceived muscle soreness following the recovery period was not significantly different between the two trials, magnitude based inferences revealed an 81% likelihood that compression garments would be more effective in attenuating the muscle soreness, coupled with a 2% likelihood it would produce a negative effect compared to the control trial. The trend towards improved perceptions of muscle soreness associated with compression garments is consistent with the literature (Davies et al. 2009; Duffield et al. 2010; Duffield and Portus 2007), notwithstanding the absence of any ergogenic benefits to performance, suggesting the possibility of a placebo effect.

Placebo effects are difficult to control for in compression garment research, and when any performance effects are found, it is often difficult to delineate from any physiological effects (MacRae et al. 2011). We acknowledge the lack of a placebo condition in the current study, and while some studies have reported use of a placebo garment, we felt that it would not be possible to blind the subjects; especially given they were all familiar with wearing compression garments on a regular basis. A limitation of the current study was that the level of pressure that the compression garments exerted on the lower-limbs of each individual subject was not measured. Identifying the level of compression would enable us to ensure that the garments were in fact graduated and could even give insight into any individual performances and the relationship to the level of compression. Conversely, the optimal levels of compression for increasing blood flow in athletic populations are relatively unknown, suggesting a future area of important research.

In conclusion, wearing lower-body compression garments during a 60-minute recovery period between two endurance cycling bouts was beneficial to 30-minute time-trial performance. The improved maintenance of power output between exercise bouts in the compression garment trial was supported by reductions in blood lactate concentration, thigh and calf girth measurements and a trend towards improved perceptions of muscle soreness. Future research should employ varying levels of compression garments and their subsequent effect on a range of blood flow measures (venous/arterial/muscle blood flow) to determine the optimal level of compression for an athletic population.

Conclusion

Wearing lower-body compression garments between two cycling bouts may assist in the recovery process, perhaps through aiding in the clearance of metabolic waste and/or attenuating the inflammatory response, thereby reducing perceptions of muscle soreness. These results can be applied to athletes and coaches looking to improve recovery between exercise bouts to allow for better quality and/or quantity of training or where subsequent performance is critical.

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References

1. Batterham AM, Hopkins WG (2006) Making meaningful inferences about magnitudes. International Journal of Sports Physiology and Performance 1: 50-57
2. Benkö T, Cooke E, McNally M, Mollan R (2001) Graduated compression stockings: knee length or thigh length. Clinical Orthopaedics and Related Research 383: 197-203
3. Bochmann RP, Seibel W, Haase E, Hietschold V, Rodel H, Deussen A (2005) External compression increases forearm perfusion. Journal of Applied Physiology 99: 2337-2344
4. Carling J, Francis K, Lorish C (1995) The effects of continuous external compression on delayed-onset muscle soreness (DOMS). International Journal of Rehabilitation and Health 1: 223-235
5. Chatard JC, Atlaoui D, Farjanel J, Louisy F, Rastel D, Guezennec CY (2004) Elastic stockings, performance and leg pain recovery in 63-year-old sportsmen. European Journal of Applied Physiology 93: 347-352
6. Davies V, Thompson KG, Cooper SM (2009) The effects of compression garments on recovery. The Journal of Strength & Conditioning Research 23: 1786-1794
7. De Glanville KM, Hamlin MJ (2012) Positive effect of lower body compression garments on subsequent 40-km cycling time trial performance. Journal of Strength & Conditioning Research 26: 480-486
8. Driller M (2012) The reliability of a 30-minute performance test on a Lode cycle ergometer. Journal of Science and Cycling 1: 21-27
9. Duffield R, Cannon J, King M (2010) The effects of compression garments on recovery of muscle performance following high-intensity sprint and plyometric exercise. Journal of Science and Medicine in Sport 13: 136-140
10. Duffield R, Edge J, Merrells R, Hawke E, Barnes M, Simcock D, Gill N (2008) The effects of compression garments on intermittent exercise performance and

recovery on consecutive days. International Journal of Sports Physiology and Performance 3: 454-468
11. Duffield R, Portus M (2007) Comparison of three types of full-body compression garments on throwing and repeat-sprint performance in cricket players. British Journal of Sports Medicine 41: 409-414
12. French DN, Thompson KG, Garland SW, Barnes CA, Portas MD, Hood PE, Wilkes G (2008) The effects of contrast bathing and compression therapy on muscular performance. Medicine & Science in Sports & Exercise 40: 1297-1306
13. Gardner AS, Stephens S, Martin DT, Lawton E, Lee H, Jenkins D (2004) Accuracy of SRM and power tap power monitoring systems for bicycling. Medicine and Science in Sports and Exercise 36: 1252-1258
14. Harriss DJ, Atkinson G (2011) Update - ethical standards in sport and exercise science research. International Journal of Sports Medicine 32: 819-821
15. Hopkins WG (1997) A new view of statistics. Will G. Hopkins
16. Howatson G, Goodall S, Van Someren KA (2009) The influence of cold water immersions on adaptation following a single bout of damaging exercise. European Journal of Applied Physiology 105: 615-621
17. Jakeman JR, Byrne C, Eston RG (2010) Lower limb compression garment improves recovery from exercise-induced muscle damage in young, active females. European Journal of Applied Physiology 109: 1137-1144
18. Jeukendrup A, Saris W, Brouns F, Kester A (1996) A new validated endurance performance test. Medicine & Science in Sports & Exercise 28: 266-270
19. Kraemer WJ, Bush JA, Wickham RB, Denegar CR, Gomez AL, Gotshalk LA, Duncan ND, Volek JS, Newton RU, Putukian M (2001a) Continuous compression as an effective therapeutic intervention in treating eccentric-exercise-induced muscle soreness. Journal of Sport Rehabilitation 10: 11-23
20. Kraemer WJ, Bush JA, Wickham RB, Denegar CR, Gomez AL, Gotshalk LA, Duncan ND, Volek JS, Putukian M, Sebastianelli WJ (2001b) Influence of compression therapy on symptoms following soft tissue injury from maximal eccentric exercise. The Journal of Orthopaedic and Sports Physical Therapy 31: 282-290
21. Kraemer WJ, Flanagan SD, Comstock BA, Fragala MS, Earp JE, Dunn-Lewis C, Ho JY, Thomas GA, Solomon-Hill G, Penwell ZR (2010) Effects of a whole body compression garment on markers of recovery after a heavy resistance workout in men and women. The Journal of Strength & Conditioning Research 24: 804-814
22. Lawrence D, Kakkar V (1980) Graduated, static, external compression of the lower limb: a physiological assessment. British Journal of Surgery 67: 119-121
23. MacRae BA, Cotter JD, Laing RM (2011) Compression garments and exercise: garment considerations, physiology and performance. Sports Medicine 41: 815-843
24. Mayberry JC, Moneta GL, De Frang RD, Porter JM (1991) The influence of elastic compression stockings on deep venous hemodynamics. Journal of vascular surgery 13: 91-100
25. O'Donnell Jr TF, Rosenthal DA, Callow AD, Ledig BL (1979) Effect of elastic compression on venous hemodynamics in postphlebitic limbs. The Journal of the American Medical Association 242: 2766-2768
26. Partsch H, Mosti G (2008) Thigh compression. Phlebology 23: 252-258
27. Ramelet AA (2002) Compression therapy. Dermatologic Surgery 28: 6-10
28. Tanner RK, Fuller KL, Ross MLR (2010) Evaluation of three portable blood lactate analysers: lactate pro, lactate scout and lactate plus. European Journal of Applied Physiology 109: 551-559
29. Thompson D, Nicholas CW, Williams C (1999) Muscular soreness following prolonged intermittent high-intensity shuttle running. Journal of Sports Sciences 17: 387-395
30. Vaile J, Halson S, Gill N, Dawson B (2008) Effect of cold water immersion on repeat cycling performance and thermoregulation in the heat. Journal of Sports Sciences 26: 431-440