P03-3 ID148

A RANDOMISED CONTROLLED TRIAL EVALUATING THE EFFECTS OF COMPRESSION GARMENTS DURING SINGLE-LEG HOPPING TO EXHAUSTION

Kurt L. Mudie, Peter J. Clothier, Joshua J. Bryers, Amitabh Gupta

University of Western Sydney, School of Science & Health
Campbelltown, NSW, Australia

The purpose of this investigation was to determine the effect of compression garments on spatiotemporal and leg mechanical characteristics during single-leg-hopping (2.2 Hz) to volitional exhaustion. This study demonstrated that compression garments had no significant effect on leg mechanical characteristics or performance parameters of single-leg hopping to volitional exhaustion. There was a significant increase in the duration of the loading phase and decrease in the flight phase from the start to the end during single-leg hopping task indicating that there may have been a shift in the motor control strategy used to preserve vertical leg stiffness and hopping frequency in a repeated and rapid loading task.

KEY WORDS: leg stiffness, fatigue, rapid loading, lower limb

INTRODUCTION: Compression garments (CG) have been used within the medical community to treat conditions such as chronic venous insufficiency (Eberhardt & Raffetto, 2005), burns and scarring (Garcia-Velasco, Ley, Mutch, Surkes, & Williams, 1978). Compression garments have been increasingly used by recreational and elite level athletes in an effort to improve performance (Scanlan, Dascombe, Reaburn, & Osborne, 2008). A number of studies have aimed to determine the physiological effects that CG have on the body during and after physical exercise (Ali, Caine, & Snow, 2007) with only a few studies investigating the possible effects on the mechanical characteristics. Greater mean power output was demonstrated during 10 repeated vertical jump efforts while wearing an above knee compression garment in volleyball players (Kraemer et al., 1996). Further, improvements in an endurance running task were observed while wearing calf compression stockings, however, these were not attributable to the small improvement in aerobic capacity (Kemmler et al., 2009). The mechanical of effect of wearing above knee CG was demonstrated with decreased muscle oscillation during a countermovement jump test, greater depth during squatting during the countermovement jump test in men and a trend towards reduced hip flexion during a 60m sprint test in both genders (Doan et al., 2003). The effect of CG on motor performance parameters and leg mechanical characteristics during rapid and repeated loading of the limb to exhaustion was of specific interest in this study. This was because CG are often used by athletes participating in sports which require repeated loading of the lower limb over prolonged periods and often to exhaustion. Therefore, the purpose of this investigation was to determine the effect of compression garments on leg mechanical characteristics and motor control parameters during single-leg hopping to volitional exhaustion.

METHODS: Thirty-eight healthy, recreationally active males with a mean age of 22.1 years (SD) (2.8), 181.0 cm (6.7) in height and 78.3 kg (10.8) in weight were recruited from the student population at the University of Western Sydney. Participants were considered to be recreationally active if they participated in sport or exercise for between 3 and 15 hours per week for the 6 months prior to testing, thus excluding sedentary and high performing populations. Ethical approval from the University of Western Sydney Human Ethics Research Committee and participant written consent were obtained prior to the commencement of testing.

Testing Procedure: All single-leg hopping trials were performed barefoot on the preferred hopping leg as reported by the participant. Each participant completed a familiarisation period followed by a series of single-leg hopping efforts on a force plate (Kistler, model 9286B, Switzerland) in synchrony with a digital metronome that emitted an audible tone at 132 beats/minute (2.2 Hz)(freeware: http://www.guitartablessons.com) from a personal laptop (Dell, Studio 1555 - PP39L, USA). Temporal and vertical ground reaction force (F_z) data were collected at a sampling frequency of 1000 Hz during trials via an A/D convertor (Kistler Type 5691A1) and recorded on a personal laptop (Lenovo, W700, USA) using Bioware® software (Version 4.0, Type 2812D). During familiarisation and experimental trials participants were required to hop with trials their hands on their waist and to stop hopping when he felt exhausted or he could not hop in synchrony with the metronome and to avoid contacting the heel with the force plate. The order of testing of the three hopping conditions (garment, control and sham) was randomly assigned. The CG's were full length (Skins™) from the pelvis to the ankle and fitted for each participant based on the manufacturer's guidelines (http://www.skins.net/en-AU/why-skins/unique-sizing-guide.aspx). The control hopping condition required the participant to hop with only loose fitting above knee shorts. The sham hopping condition involved applying a 20 cm length of 5 cm wide rigid sports tape (Leuko™) over the knee extensors (between the anterior superior iliac spine and the superior border of the patella) and ankle plantar flexors (between the popliteal crease and the calcaneal tuberosity). The primary investigator provided verbal feedback to each participant during each trial to ensure that the participant avoided translating across the force plate, avoided contacting the heel with the force plate, maintained synchrony with the audible metronome and performed the trial to their self-perceived level of exhaustion.

Data Processing: Vertical ground reaction force (Fz) data for each trial were filtered using a Butterworth filter with a low-pass cut-off set at 33Hz (Bioware version 4.0, Type 2812D) and exported to an excel spread sheet (Microsoft Office Excel, 2007) for further analysis. A hopping cycle was defined as a consecutive flight phase and contact phase from the F_z recording. Hop cycles included in the analyses had to be within 5% of the target hopping frequency of 2.2 Hz (i.e. from 1.98 to 2.42Hz). The dependant variables for each hop cycle during the start (first 10 consecutive hop cycles) and end (last 10 consecutive hop cycles) periods were determined. A mean score for each dependant variable was calculated for the start and end periods for each trial. Dependant variables that were determined included: duration of trial, time in flight (from start of flight to initial contact (IC)), time in loading phase (from IC to peak F_z), time in contact (from IC to toe-off), normalised peak F_{zN} ($N.kg^{-1}$), vertical displacement of the centre of mass (COM) during loading (Z_l) and normalised vertical stiffness (K_N) ($N.kg^{-1}.m^{-1}$). The law of falling bodies was used to determine the vertical displacement of the COM during loading phase (Table 1). Normalised vertical stiffness (K_N) was calculated as the quotient of F_{zN} and Z_l.

Table 1

Calculation of the vertical displacement of the centre of mass during loading phase.

Equation 1 $z_f = \frac{1}{2} \cdot g \cdot \left(\frac{T_f}{2} \right)^2$	Where Z_f was the vertical displacement of the COM from peak height of the centre of mass (COM) during the flight phase to initial contact (IC), g was the acceleration due to gravity (9.81 $m.s^{-1}$) and T_f was the total time in flight phase. This method assumes that the velocity of the COM at the peak height during flight phase was 0m/s as there was a change in direction of the COM that occurred at half flight phase.
Equation 2 $v_i = \sqrt{2.g.z_f}$	Where v_i was the velocity at IC, g was the acceleration due to gravity (9.81 $m.s^{-1}$) and z_f was vertical displacement of the COM during the second half of flight phase.
Equation 3 $z_l = \frac{1}{2}(v_i + v_f) \cdot t_l$	Where z_l was the vertical displacement of the COM during loading phase, v_i was the velocity at IC, v_f was velocity at peak vertical ground reaction force (assumed to be 0m/s) and t_l was the duration of loading phase.

Statistical Analyses: A one-way repeated measures analysis of variance (ANOVA) was performed to determine differences between trials for total hopping duration. Two-way repeated ANOVA was performed to determine differences in spatiotemporal and leg mechanical characteristics, with significance accepted at $p<0.05$. Bonferroni correction was made for all analyses to reduce the risk of making a type 1 error. When significant main effects were determined, post hoc tests were performed to identify the level at which significant differences were present with Bonferroni correction made to determine the alpha value at which significance was accepted.

RESULTS: There was no significant difference ($p=0.76$) in total duration of hopping between conditions (garment (mean (SD)) 89.63s (36.27), no garment 88.53s (27.49) and sham 91.34s (27.68)). There were no systematic differences detected for any dependant variables between the three hopping conditions ($p>0.05$). There was a significant decrease in t_f at from start to finish ($p<0.01$) (Table 2). Post hoc paired t-tests demonstrated that there was a similar decrease in t_f for each hopping condition ranging from 0.01 to 0.02s ($p\leq0.004$). There was a significant increase in t_c from the start to the end period ($p=0.15$).There was a significant decrease in Z_f from start to finish ($p<0.01$). Post hoc paired t-tests demonstrated that there was a similar decrease in Z_f for each hopping condition ranging from 3 to 4mm ($p\leq0.005$). There was a significant decrease in Z_l from start to finish ($p<0.01$). Post hoc paired t-tests demonstrated that there was a similar decrease in Z_l for each hopping condition ranging from 4 to 6mm ($p\leq0.003$). There was a significant increase in K_N from start to finish ($p=0.001$) ranging from a 9.1 to 12.2%.

Table 2
Spatiotemporal and leg mechanical characteristics (mean (SD)) at the start and end periods during single-leg hopping to volitional exhaustion with and without a compression garment and with a sham intervention.

	Garment		No Garment		Sham	
	Start	End	Start	End	Start	End
t_f (ms)*	115 (24)	103 (231)	115 (22)	99 (24)	111 (22)	100 (24)
t_l (ms)	166 (16)	167 (18)	165 (14)	170 (22)	168 (17)	171 (18)
t_c (ms)*	339 (24)	351 (25)	340 (22)	355 (27)	344 (25)	355 (26)
Z_f (mm)*	17 (7)	14 (6)	17 (6)	13 (6)	16 (6)	13 (6)
Z_l (mm)*	46 (7)	42 (8)	46 (8)	41 (7)	45 (7)	41 (7)
F_{zN} ($N.kg^{-1}$)	24 (3)	24 (3)	24 (2)	23 (3)	24 (2)	23 (3)
K_N*($N.kg^{-1}.m^{-1}$)	529 (61)	584 (109)	533 (70)	590 (107)	538 (79)	581 (96)

t_f -time in flight phase; t_l - time in loading phase; Z_f - vertical height displacement of the COM during flight phase; Z_l - vertical height displacement of the COM during loading phase; F_{zN} - normalised peak vertical ground reaction force; K_N - normalised vertical leg stiffness; *significant difference between start and end periods ($p<0.05$)

DISCUSSION: Compression garments did not have any significant effect on spatiotemporal or leg mechanical characteristics during this task, nor did they lead to an increase in time to volitional exhaustion. The main finding of this investigation was that there was a significant increase in K_N as participants approached volitional exhaustion during single-leg hopping. Previously it has been demonstrated that during a double-leg hopping task to fatigue, ground contact time increased while maintaining a hopping frequency of 2Hz (Bonnard, Sirin, Oddsson, & Thorstensson, 1994). This contrasts the findings of the current study that demonstrated an increase in K_N, increase in t_c and decrease in t_f at the end compared to the start period while hopping at 2.2Hz. The difference in results to the study by Bonnard et al. (1994) may be due to differences in how the limb was able to adapt when the task was single-legged rather than being double-legged. The current findings suggest that CG do not influence lower limb mechanical characteristics when the leg was modelled as a massless spring and vertical leg stiffness was calculated. Changes to neuromuscular characteristics were reported by Bonnard et al. (1994) with the finding of invariant medial gastrocnemius muscle function and change in the synergy between knee and ankle joint moments (Bonnard, et al., 1994). Therefore, in the current study it was possible that despite no detectable differences in spatiotemporal or leg mechanical characteristics with or without compression garments, there may have been neuromuscular or kinematic adaptations.

CONCLUSIONS: Compression garments fitted to manufacturer guidelines had no significant effect on temporal or mechanical characteristics during single leg hopping to volitional exhaustion. Wearing CG did not increase the time to volitional exhaustion indicating no performance benefit in this task. The significant increase observed in the contact phase and decrease in the flight phase from the start to the end of hopping suggests there may have been a shift in the motor control strategy used to preserve vertical leg stiffness and hopping frequency with increasing fatigue.

REFERENCES:

Ali, A., Caine, M. P., & Snow, B. G. (2007). Graduated compression stockings: physiological and perceptual responses during and after exercise. *Journal of Sports Science, 25*(4), 413-419.

Bonnard, M., Sirin, A. V., Oddsson, L., & Thorstensson, A. (1994). Different strategies to compensate for the effects of fatigue revealed by neuromuscular adaptation processes in humans. *Neuroscience Letters, 166*, 101-105.

Doan, B. K., Kwon, Y. H., Newton, R. U., Shim, J., Popper, E. M., Rogers, R. A., . . . Kraemer, W. J. (2003). Evaluation of a lower-body compression garment. *Journal of Sports Sciences, 21*(8), 601-610.

Eberhardt, R. T., & Raffetto, J. D. (2005). Chronic venous insufficiency. *Circulation, 111*(18), 2398-2409.

Garcia-Velasco, M., Ley, R., Mutch, D., Surkes, N., & Williams, H. B. (1978). Compression treatment of hypertrophic scars in burned children. *Canadian Journal of Surgery, 21*(5), 450-452.

Kemmler, W., von Stengel, S., Köckritz, C., Mayhew, J., Wassermann, A., & Zapf, J. (2009). Effect of compression stockings on running performance in men runners. *Journal of Strength and Conditioning Research, 23*(1), 101-105.

Kraemer, W. J., Bush, J. A., Bauer, J. A., Triplet-McBride, N. T., Paxton, N. J., Clemson, A., . . . Newton, R. U. (1996). Influence of comrpession garments on vertical jump performance in NCAA Division I volleyball players. *Journal of Strength and Conditioning Research, 10*(3), 180-183.

Scanlan, A. T., Dascombe, B. J., Reaburn, P. R., & Osborne, M. (2008). The effects of wearing lower-body compression garments during endurance cycling. *International Journal of Sports Physiology and Performance, 3*(4), 424-438.