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The effects of lower-body compression garments on walking performance and perceived exertion in adults with CVD risk factors.

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ABSTRACT

Objectives. Compression garments (CG) are used by athletes in attempts to enhance performance and recovery, although evidence to support their use is equivocal. Reducing the exertion experienced during exercise may encourage sedentary individuals to increase physical activity. The aim of this study was to assess the effect of CG on walking performance (self-paced and enforced pace) and rate of perceived exertion (RPE) in adults who presented with two or more CVD risk factors. Participants (n=15, 10 female, 58.9 ± 11.5 years, BMI 27.5± 4.5 $kg \cdot m^2$) were recruited. *Design*. A repeated measures design. *Methods.* Participants were randomised to Modified Bruce Protocol (MPB, enforced pace), or the 6 minute walk test (6 MWT, self-paced), and completed the test wearing compression garments (CG) or normal exercise clothes (CON). Outcome measures included stage completed, gross efficiency (%) and RPE in MBP, and distance walked (m) and RPE in 6 MWT. *Results*. In the MBP participants had a higher RPE (15.5 ±2.5 vs 14.3 ±2.2) and a lower efficiency (19.1 ±5.9 vs 21.1 ±6.7) in the CG condition compared with CON, p <0.05. In the 6 MWT participants walked 9% less in the CG condition (p<0.05) but did not have a lower RPE. *Conclusion.* Compared with previous studies reporting enhanced or no effects of CG on performance or RPE, this study shows adverse effects of CG in untrained individuals with CVD risk factors. The mechanisms underlying this negative effect require further exploration. Use of garments designed for the athletic individuals may not be suitable for the wider population.

Keywords: Adult, physical activity, exercise, risk, effort

INTRODUCTION

The use of compression garments (CG) to facilitate sports performance and recovery is becoming increasingly popular. Originally designed for post-surgical use, with compression graduated from ankle to hip, they were used to enhance blood flow. They are also used to prevent venous pooling that frequently occurs during pregnancy and long distance travel. The commercial claims for CG suggest they can improve sports performance, and reduce fatigue and muscle injury. Investigations into CG effects on speed[1], endurance[2], running economy[3], oxygen consumption[4] and recovery[5] provide mixed results. The strongest support from these studies is for a type of 'placebo effect' mediated by heightened feelings of support[6]. Wearers report lower ratings of perceived exertion (RPE) although this is not usually accompanied by improvements in performance[7]. In older athletes (age 63 years) CG worn during recovery increased power output during a subsequent cycling bout[8]. Further, the subjects reported reduced leg discomfort during cycling, although this pain rating was not associated improved performance.

As age increases, physical activity declines. Even adults that have been prescribed exercise for health reasons, frequently fail to achieve a target amount of activity. For instance, only 36% of subjects who were referred to cardiac rehabilitation fully completed their prescribed exercise sessions[9]. Many barriers to adherence to exercise programmes, such as access to facilities, are difficult to address. However, if the activity was made to feel more comfortable and less demanding adherence may increase.

Studies to date assessing the effect of CG on performance may be limited in that participants have already have a high work capacity, so any changes seen would be minimal. Older and less physically fit individuals may have more potential for increasing performance. Theoretically, compression will increase pressure in lower limb vessels, so enhancing diffusion capacity, and enhancing exercise capacity.

Thus, the aim of this study was to determine the effects of wearing CG on RPE and walking performance in adults with CVD risk factors during prescribed workload and self-paced walking; Modified Bruce Protocol [MBP] and self-paced 6 minute walk test [6 MWT]. Externally guided exercise facilitates comparison of RPE at the same workload. In self-paced exercise, workload varies according to RPE. This dual-protocol approach was chosen in an attempt to allow better understanding of the mechanisms by which CG may influence responses to exercise and exercise performance.

The primary hypothesis was that wearing CG would reduce RPE during a treadmill-based walking protocol. The second hypothesis was that wearing CG would increase walking performance in terms of stage reached (MBP) or distance walked (6 MWT).

METHODS

Five males and 10 females, ages 58.9 years (±11.5, range 40 to 73 years), with a BMI 27.5 (±4.5 range 20.4 to 36.1 kg m^2) were recruited. Ethical approval for the study was given by the University of Essex Ethics Committee. Inclusion criteria were current diagnosis of cardiovascular disease, previous myocardial infarction, type 2 diabetes or clustered metabolic risk[10]. Unstable angina was an exclusion criterion. Details of participant risk factors are available as supplementary material.

We used a repeated measures, double randomised cross-over design that required participants to attend two separate testing sessions, one week apart, at the same time of day. Participants were asked to maintain normal activity between trials, and refrain from strenuous activity 24 hours prior to testing. Room temperature was the same in each trial (19 $^{\circ}$C). Participants were randomly selected to either MBP or 6 MWT group, then randomly assigned to wear CG during their first trial (Time 1) or their second trial (Time 2, see Figure 1). When not wearing CG, participants wore their own loose exercise trousers. Both walking protocols took place on a motorised treadmill (Saturn, HP-Cosmos, Germany).

After 3 minutes of quiet sitting, duplicate resting blood pressure was measured (MX3Plus Omron digital blood pressure monitor HEM-742-E), with the lowest value recorded. Expired gases (Oxycon-MasterScreen™ CPX) and heart rate (Polar RCX5 G5 Oy, Finland) were continually recorded throughout the test. At the end of each stage (MPB) or each minute (6 MWT), participants were asked to report their RPE[11]. RPE was assessed on a 6-20 point scale (shown on a large chart) with participants verbally stating the number which best reflected their effort. Upon cessation of the test, blood pressure was recorded. Expired gas data were exported in 5 second epochs for analysis. In the CG condition, BP was measured whilst participants were wearing the CG both pre and post exercise. Height (m), weight (kg) and waist circumference (cm) were measured in duplicate using standard procedure.

The Bruce Protocol has seven stages, each lasting three minutes, with speed and incline increasing at each stage. The first stage starts 2.7 km h^{-1} at a 10% incline and reaches 8.8 km h^{-1} (at 20% incline The Modified Bruce protocol has two additional; stage 1 is at 2.7 km h^{-1} at 0% incline, stage 2 is at 2.7 km h^{-1} at 5% incline, and then stage 3 is the start (Stage 1) of the Bruce protocol, and continues to increase in the same manner. The test was terminated when subjects could no longer maintain the required pace (volitional exhaustion) or when heart rate exceeded age –related predicted maximum (220-age).

The 6 MWT test is used to assess functional capacity in a wide range of populations with varying levels of exercise capacity. Participants usually perform the 6 MWT by walking shuttles across the ground but in the current study the test was conducted on a treadmill in order to make it more comparable to the MBP. The treadmill was set at a 1% incline to reflect natural walking. Participants were instructed to “Adjust the speed accordingly and try to go as far as you can in 6 minutes”.

Participants were allowed to increase and decrease the speed at will, but were encouraged to maintain a fast pace. Participants were blinded to speed but not to time.

The CG used in the current study were Skins ™ Compression A400 Long (ankle to waist) Tights (Riverwood, Australia) and were fit for each subject according to the manufacturer's instructions. Fabric is 76% nylon and 24% elastane. The purpose of the CG fit is to ensure that garment movement is minimal and congruent with the skin. Participants put on the CG 5 minutes before the exercise commenced. The exerted pressure was evaluated by the Picopress® pressure monitor. Coefficient of variation for this has been reported as 2.8% [12]. Pressure measures were recorded at 5 anatomical locations; medial calf and posterior calf (at widest part), anterior thigh and posterior thigh (midpoint between greater trochanter and lateral epicondyle), and gluteus maximus (widest part). A pressure bladder was placed between the subject's skin and the CG to access the pressure on each landmark.

Data from MPB and 6 MWT were analysed separately. For the MBP, final completed stage, RPE, VO_2 (ml kg^{-1} min^{-1}) and GE (gross efficiency as %) were compared using paired t-tests at the final stage that was completed across conditions. For example if stage 4 was completed in trial 1, but only stage 3 competed in trial 2, then stage 3 was compared across trials. GE was calculated as mechanical power / metabolic power; $GE=PO/P_{met} *100$, where PO is the work output (Watts) and P_{met} is $VO_2 * [(4940*RER +16090)/60]$[13]. RPE at exhaustion (not matched stage) is also given.

For 6 MWT, distance walked (m), speed at 3 and 6 minutes (km h^{-1}), RPE at 3 minutes and final RPE, and peak VO_2 (ml kg^{-1} min^{-1}) were compared between conditions using paired t-tests.
Percent change from baseline was calculated for systolic and diastolic blood pressure (mmHg) and compared using paired t-tests, for both MBP and 6 MWT.
Statistical significance was set at alpha =0.05. Cohen's d (difference in group mean / average SD) was calculated, with effect size of 0.2 considered 'small', 0.5 as 'medium' and 0.8 as 'large'.

RESULTS

Compression values (mmHg) at the five measurement points were as follows; medial calf 12.5 (±3.6), posterior calf 11.4 (±2.8), anterior thigh 5.3 (±1.7), posterior thigh 5.1 (±1.8) gluteus 5.7 (±2.0).

Modified Bruce Protocol: Four of the eight participants achieved a VO_2 peak more than 1SD below their age and gender predicted value[14] in the CON condition. One participant continued longer in the CG condition, three continued longer in the CON condition, and four continued for a similar time (i.e. reached exhaustion during the same level) in each trial.

Participants rated the CON condition as requiring less exertion (RPE at final completed stage, t (7) =3.0, p=0.02) and had a lower VO_2 in the final completed stage (t (7) =3.4, p=0.01). GE was lower in the CON condition in the final stage completed across both trials (t (7) =2.8, p=0.03), see table 1. RPE at exhaustion was higher in CG condition but there was no difference between trials (p>0.05)

At baseline mean blood pressure (mmHg) prior to the CON trial was 137/81 (±22/14), and in the CG trial was 138/79 (±21/11). After exercise this increased to 168/85 (±28/13) in CON and 160/82 (±20/10) in the CG condition. There was no significant difference in percent change in SBP or DBP across trials (table 1).

6MWT: All participants walked within age expected norms, except one male who walked >1 SD above predicted[15] All participants walked further in the CON condition. In the CON condition, participants walked an average of 9% further compared with the CG condition (t (6)=3.3, p=0.02), table 2.

Mean blood pressure (mmHg) prior to the CON trial was 139/78mmHg (±21/10), increasing to 159 /72 (±29/9) and in the CG trial was 141/77 mmHg (±17/10) increasing to 172/74 (±28/9). There was no significant difference in change in SBP or DBP across trials.

DISCUSSION

The aims of this study were to examine the effects of CG on performance and RPE during externally and self-paced walking in adults at risk of CVD.

Participants' RPE was 1.2 points higher when wearing CG compared with CON in the MBP (with a moderate effect size of d=0.51) at a comparable time point. RPE was slightly higher (non-significant, effect size d=0.20) in the CG toward the end of 6 MWT, despite a lower self-selected walking pace.

Part of the perceived exertion may have been due to the unfamiliarity with tight compression clothing. Even trained athletes, who are likely used to wearing Lycra based clothing rate CG that have a high compression value as uncomfortable. Ali et al[4] found that compression above 23 mmHg was rated as uncomfortable. The compression values in the current study are much lower (rated as a medium or low compression in Ali et al's study), but still higher than the CON (no compression) condition. Although participants used 'positive' words or phrases to describe the comfort of the garments, such as 'supportive' and 'made me feel lighter', the unfamiliar sensation may have altered perception. Similarly, it is possible that the increased skin temperature reported in several studies [5,16,17] but not measured here, may influence the participants' perceived exertion.

Few studies to date report a positive influence of CG on whole body RPE. For example, Born et al[18] and Miyamoto & Kawakami[19] report reduced leg muscle 'RPE' as a result of CG, but did not find a reduced whole body perceived exertion. However, Faulkner et al[20] found both knee length and full length CG resulted in a lower RPE when completing a 400m run, compared with no compression.

Compression values (mmHg) for the full length garments reported by Faulkner[20] were similar to those reported in the current study. However, participants in Faulkner's study were young male athletes and so not comparable in terms of training status or importantly body composition. BMI of subjects in the current study ranged from 20.4 to 36.1 kg·m^2. Fitting of compression garments is based on weight and height, but people in the same dimensional range are likely to vary extensively in morphology[21]. Given the low training status of the subjects in the current study, along with the high BMI of some, it is likely that many subjects had a high fat mass. The effects of compression on fat mass as opposed to muscle mass, and the consequent physiological effects are likely to be very different.

Across both walking protocols, performance was reduced in the CG condition. In MBP participants completed fewer stages whilst wearing the CG (although there was no significant difference between trials in this protocol).

Distance walked was 9% less in the CG trial in the 6 MWT ($p<0.05$). This is of particular importance as it more reflective of the self-paced nature of physical activity that is common in rehabilitation classes. Although some studies report increases in explosive power measures (such as counter movement jumps)[16,22] few studies have found positive effects of CG on endurance performance. Kemmler et al[1] showed increases in total work and work duration as part of a running to exhaustion trial as a result of lower leg CG. Similarly, Bringard et al[3] reported a reduced oxygen cost of running (only at 12 km h^{-1}). This reduced oxygen cost implies a greater efficiency. However, a far greater number of studies that used a similar protocol to the current study report no effect of CG on performance or economy. [4,6,23] In the MBP we found a higher VO_2 at the same comparable stage in the CG condition. The mechanisms by which CG may increase oxygen requirement in the current study are unclear. Again, alterations in temperature will alter local, and potentially central, haemodynamics, potentially altering whole body oxygen demand. Similarly, the compression may have altered flow rate and perfusion. Bochmannet al[24] reported increases in forearm blood flow and perfusion as a result of external compression, which was enhanced by light exercise. If a similar increase in perfusion was occurring in participants in the CG condition in the current study, this may explain the increased VO_2. However, if an increase in perfusion did occur, it was not accompanied by an increase in performance or a decrease in perceived exertion, so the increase in VO_2 in CG was likely due to other reasons.

Lack of familiarisation to compressive clothing may have altered the normal gait of the participants. Compression alters many factors that contribute to normal gait; proprioception and balance[25] and range of motion[16]. The reduction in range of motion was shown at the hip joint during a 60m run in healthy males wearing knee length compression shorts by Doan and colleagues. Although the demographic of the participants and the nature of the test differ in Doan's study to the current study, it is possible that the increased resistance altered gait during the CG condition. This may have negatively influenced normal walking economy, i.e. increasing VO_2. It is a limitation of this study that gait was not analysed during the exercise.

Systolic blood pressure increased in all conditions as a result of exercise, as would be expected. The effect of compression of venous pooling is unclear, especially in upright postures or during exercise. At compressions of 20 to 30 mmHg (higher than reported in the current study) there is little evidence of decreased venous diameter or altered flow in healthy subjects in upright positions[26]. Privett and colleagues[27] showed that compression stockings can help maintain blood pressure in orthostatically intolerant athletes post-exercise, but few studies report the effect of compression garments on blood pressure either during or post-exercise. MacRae and colleagues[28] report small limited effects of CG on CV variables (increased cardiac output and HR drift but no effect on arterial pressure) during submaximal exercise. They conclude the mild compression commercial garments provide fails to add to the effectiveness of skeletal muscle pumps and venous valves in healthy individuals. The current study involved adults with potentially compromised CV systems who may have limited exercise tolerance, and possibly a different response to CG. This was apparent in the MBP where four participants achieved a VO_2 max lower than age expected norms. The limited exercise tolerance displayed makes comparison with athlete based studies difficult. However use of a repeated measures design reduces variability between conditions. Further the participants are highly representative of the type of individuals who receive GP exercise referral.

Increases in blood pressure above normal exercise related changes could be potentially harmful for subjects who are already hypertensive. Conclusions regarding the effect of compression on blood pressure cannot be gained from this study due to the range of cardiovascular risk factors presented, the degree of hypertension and the fact that 2 participants were taking medication that mediated blood pressure.

Conclusion

If participants perceive exercise to be easier and more comfortable whilst wearing CG they may be encouraged to do more activity. However, walking performance and perceived effort were negatively affected by the use of compression garments in this population. It is possible that further familiarisation with the garments may reduce the participants RPE, which likely affected their performance, particularly in the 6 MWT. The effect of compression on gait and on CV strain in 'non-healthy' populations, and also requires further assessment.

Practical implications

- Commercially available garments, such as the ones used in this study, are not designed for use outside the athletic population and so caution is advised in relation to their widespread use.

- Familiarisation with the garments is recommended as the constriction experienced will likely alter RPE and potentially gait.
- The effects of compression garments on blood pressure in hypertensive subjects should be monitored.

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Table 1. Performance, physiological and perception of effort data for Modified Bruce Protocol across two conditions (CG and CON), n=8. Data are mean ±SD.

	CG	CON	Effect size (Cohen)
Final completed stage	4.75 ±1.6	5.00 ±1.3	
RPE at final completed stage †	15.5 ±2.5*	14.3 ±2.2*	*d*=0.51
RPE at exhaustion (regardless of stage)	15.6 ±2.4	14.8 ±2.0	*d=0.36*
$\dot{V}O_2$ at final stage (ml kg^{-1} min^{-1}) †	27.3 ±5.6*	24.8 ±5.6*	*d*=0.45
GE (%) at final stage †	19.1 ±5.9*	21.1 ±6.7*	*d*=0.31
HR peak (bpm)	139 ±26.2	141 ±22.7	*d*=0.20
% change in SBP	20.9 ±11.2	24.1 ±10.8	*d*=0.29
% change in DBP	7.9 ±20.0	4.1 ±20.0	*d*=0.19

† individual stage completed across both trials, * significant difference between groups, $p<0.05$.

Table 2. Performance, physiological and perception of effort data for 6 minute Walk Test across two conditions (CG and CON), n=7. Data are mean ±SD.

	CG	CON	Effect size (Cohen)
Distance walked (m)	562 ±126*	612 ±115*	*d*=0.44
Final RPE	16.0 ±1.8	15.6 ±2.4	*d*=0.20
Speed at 3 min (km $^{h\ -1}$)	5.85 ±0.85	6.03 ±0.74	*d*=0.22
(m s^{-1})	1.6 ±0.2	1.7 ±0.2	
Speed at 6 min (km h^{-1})	6.7 ±0.9	7.2 ±0.6	*d*=0.65
(m s^{-1})	1.9 ±0.2	2.0 ± 0.2	
Peak VO_2 (ml kg min^{-1})	23.4 ± 4.3	22.7 ± 4.6	*d*=0.16
% change in SBP	26.6 ±22.0	14.6 ±9.8	*d*=0.70
% change in DBP	1.2 ±11.0	-6.5 ±10.1	*d*=0.50

* significant difference between groups, p<0.05

Figure 1. Double randomised cross over design.

6MWT (6 minute walk test), MPB (Modified Bruce Protocol), CG (Compression Garment), CON (Control condition), T1 (time1), T2 (time2)

Figure(s)

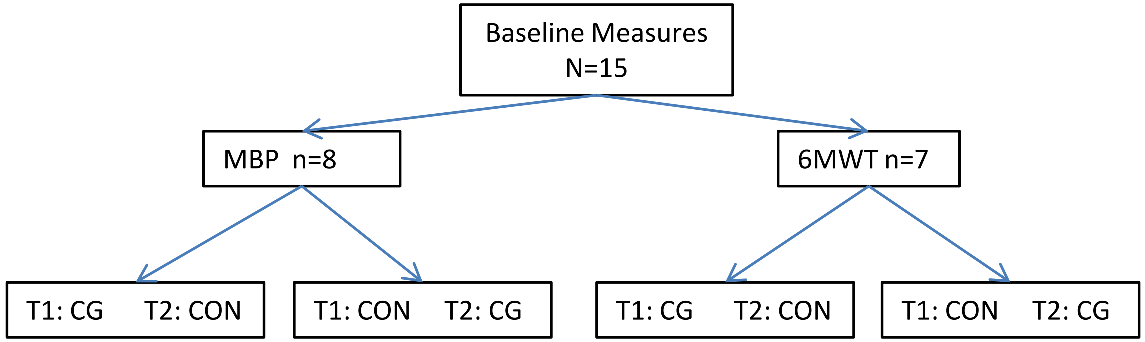

Figure 1. Double randomised cross over design.