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Human Kinetics
BRIEF REPORT

The Effect of Compression Garments on Performance in Elite Winter Biathletes

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Purpose: To evaluate the effects of wearing upper- and lower-body compression garments on cross-country skiing performance in elite winter biathletes. ***Methods:*** A total of 7 senior biathletes (4 men and 3 women) from the Swedish national team performed 2 exercise trials in a randomized and counterbalanced order, wearing either commercially available upper- and lower-body compression garments (COMP) or a standard winter-biathlon racing suit (CON). In each trial, the athletes roller-skied on a customized treadmill, completing a time trial simulating the skiing duration of a biathlon sprint race, followed by a time-to-exhaustion test designed to elicit exhaustion within ~60 to 90 seconds. Heart rate, blood lactate concentration, rating of perceived exertion, thermal sensation, and thermal comfort were monitored throughout each trial, while muscle soreness was measured up to 48 hours after each trial. ***Results:*** Pressure exerted by the clothing was significantly higher at all anatomical sites for COMP compared with CON ($P \leq .002$). Wearing COMP led to small positive effects on time-trial ($d = 0.31$) and time-to-exhaustion test ($d = 0.31$) performances compared with CON, but these differences were not statistically significant ($P > .05$). No significant differences were found for any physiological (heart rate or blood lactate concentration) or subjective (rating of perceived exertion, thermal sensation, thermal comfort, or muscle soreness) responses between COMP and CON ($P > .05$). ***Conclusion:*** Wearing COMP during maximal cross-country skiing may have small but worthwhile beneficial effects on performance for some individuals. Due to individual variation, athletes are advised to test COMP prior to competition.

Keywords: biathlon, commercially available, roller-skiing, time trial, world class

Manufacturers claim that compression garments can improve performance when worn during exercise. A number of mechanisms support this assertion, including an increase in deep-muscle oxygenation, a reduction in muscle oscillation, and improved venous return during exercise, which may facilitate the clearance of metabolites and increase stroke volume.[1] Although studies using running and cycling exercise have shown limited evidence to support improvements in physiological markers, some research has shown that compression garments may marginally improve time-to-exhaustion (TTE) and time-trial (TT) performance.[2]

Few studies have assessed the effects of compression garments during cross-country (XC) skiing. Heil and McLaren[3] reported that upper- and lower-body garments led to reductions in heart rate (HR) and blood lactate (BLa) concentration when roller-skiing at various submaximal intensities and, as a result, concluded that a 2-piece compression garment led to mildly positive effects on factors related to XC-skiing performance. However, Sperlich et al[4] reported no beneficial effects of an upper-body compression garment on repeated 3-min sprint performance in nonelite men using double-poling ski ergometry.

To date, no studies have investigated the effects of wearing whole-body compression clothing during skate XC skiing in elite athletes. Therefore, the aim of this study was to assess the effects of wearing upper- and lower-body compression garments on laboratory-based roller-skiing performance in elite biathletes, using ski durations and techniques simulating the demands of biathlon racing. It was hypothesized that wearing compression clothing would lead to significantly improved maximal TT performance and extend TTE.

Methods

A total of 7 senior biathletes (4 men and 3 women; age 25.1 [3.1] y, height 176.5 [6.8] cm, and body mass 71.6 [7.9] kg) were recruited from the Swedish national team to participate in the study, which was carried out during preseason (in August). Four of the participants (2 men and 2 women) were medalists at the PyeongChang Olympic Games, and the remaining athletes have all medaled at international competitions. Each participant completed a health questionnaire and provided written informed consent prior to participating. The study was conducted according to the Declaration of Helsinki and was approved by the regional ethical review board of Umeå University, Umeå, Sweden (#2016-506-31M).

Using a randomized and counterbalanced crossover design, the athletes completed 2 trials, wearing either commercially available (2XU Pty Ltd, Melbourne, Australia) upper- and lower-body compression garments (COMP) or their standard racing suit (CON). Pressure in all garments was measured prior to the trials using a previously validated[5] body pressure measuring device (Kikuhime; TT Meditrade, Søleddet, Denmark) at the midpoint of the biceps brachii, triceps brachii, brachioradialis, rectus femoris, and gastrocnemius lateral.[1] Three repeated measurements were taken at each site with the athletes in a standing position, and mean values were used in the data analyses. Participants were instructed to avoid alcohol and caffeine for 24 h before the trials and to eat a standardized breakfast prior to both trials, which were performed at the same time of day between 8:00 AM and 12:00 PM.

On arrival at the laboratory, height, body mass, and resting HR were recorded (M400; Polar Electro Oy, Kempele, Finland),

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and a resting blood sample was taken from the fingertip for the subsequent analysis of BLa concentration (Biosen C-line; EKF Diagnostic GmbH, Magdeburg, Germany). Thermal sensation (TS) and thermal comfort (TC) ratings were recorded using an adapted ASHRAE 9-point analog sensation scale[6] and the Bedford 7-point scale,[7] respectively. Ambient laboratory conditions were ~20°C and 45% humidity, and a standing 3-speed fan (Clas Ohlson, Insjön, Sweden) was used at full power throughout all exercise trials.

Athletes performed the exercise tests on a motor-driven treadmill (Rodby RL 3000, Rodby, Vänge, Sweden) fitted with a laser system allowing self-regulation of speed.[8] Skate skiing subtechniques were self-selected during the tests, allowing athletes to simulate race conditions and maximize performance on each occasion. All athletes were well accustomed to maximal roller-skiing on this treadmill using the skating technique, as well as the standardized roller skis (Pro-Ski Classic C2, Sterners, Dala-Järna, Sweden). The treadmill was set to 3.5° and 4.5° inclines for women and men, respectively, and the trials began with a 15-min warm-up at intermittent speeds of 8 to 16 km/h for women and 9 to 17 km/h for men. Following a 3-min rest, a performance TT was completed lasting 15 min for women and 20 min for men (to simulate the skiing durations of a biathlon sprint event), and athletes were instructed to cover as much distance as possible. On completing the TT, athletes had 3 min of rest before completing a TTE test, which was performed at 20 km/h for women and 22 km/h for men. Athletes were instructed to continue skiing for as long as possible, and the protocol was designed to elicit exhaustion within ~60 to 90 s (ie, an exhaustive anaerobic effort).

The HR was averaged for 30 s at rest with athletes standing still on the treadmill and during the last 10 s of the warm-up, TT, and TTE test. Capillary blood samples were obtained for the analysis of BLa concentration 1 min after the warm-up, TT, TTE test, and cooldown. A rating of perceived exertion (RPE) was obtained every 5 min during the warm-up and immediately after the TT and TTE test.[9] Ratings of TS and TC were recorded immediately after the warm-up, TT, and TTE test. Muscle soreness was measured 8 min after the cooldown following a full-depth, body-weight squat using a 10-point numerical pain-rating scale anchored at 0 (no pain at all) and 10 (unbearable pain).[10] The athletes repeated this process after a further 24 and 48 h, and they also reported their muscle soreness scores to the research team via text message.

Statistical analyses were performed using IBM SPSS Statistics for Windows (version 24.0; IBM Corp, Armonk, NY), and the alpha level was set to ≤.05. Parametric data are reported as mean (SD) and were analyzed using paired samples *t* tests to compare responses to COMP and CON, and a 2-way repeated-measures analysis of variance to assess changes between conditions over time. Nonparametric variables are reported as median (range) and were analyzed using the Wilcoxon signed-rank test. Effect size was calculated using Cohen *d* (*d*) and partial eta-squared (η_p^2) for the paired samples and 2-way repeated-measures analyses, respectively.[11]

Results

Garment pressure was significantly greater for COMP compared with CON at all of the following sites ($P \le .002$): biceps brachii (7.4 [2.2] vs 1.4 [1.0] mm Hg), triceps brachii (7.9 [2.2] vs 2.1 [1.2] mm Hg), brachioradialis (13.1 [4.5] vs 3.9 [1.9] mm Hg), rectus femoris (13.3 [2.3] vs 4.7 [1.7] mm Hg), and gastrocnemius lateral head (19.9 [5.9] vs 7.9 [2.0] mm Hg).

Compared with CON, there were small beneficial effects of COMP on performance during the TT and TTE test ($d = 0.31$ and 0.37, respectively), but these effects were not statistically significant ($P = .273$ and .212, respectively) (Figure 1). When comparing the 10% intervals during the TT, no main effect of intervention (COMP vs CON) was observed ($F_{1,6} = 1.918$, $P = .215$, $\eta_p^2 = .242$), but there was a main effect of time ($F_{9,54} = 6.147$, $P < .001$, $\eta_p^2 = .517$) (Figure 2).

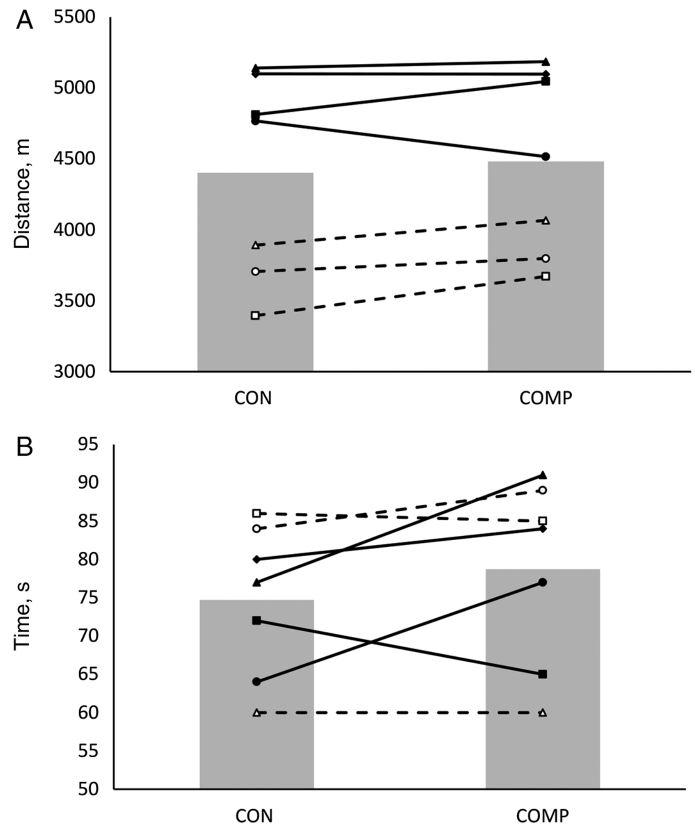

Figure 1 — (A) Distance covered during the self-paced roller-skiing TT and (B) TTE at a fixed speed when wearing compression (COMP) or control (CON) garments. Solid bars represent the group mean, and individual responses are represented by solid (men) and dashed (women) lines, with individual markers distinguishing each athlete. TT indicates time trial; TTE, time to exhaustion.

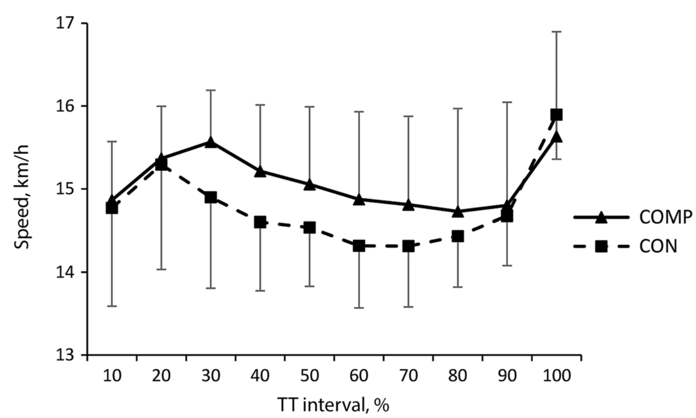

Figure 2 — Mean (SD) treadmill roller-skiing speed (in km/h) during each 10% of the self-paced roller-skiing TT when wearing compression (COMP) or control (CON) garments. TT indicates time trial.

Table 1 Mean (SD) HR and BLa Concentration, as well as Median (Range) RPE, TS, and TC Measured at Rest and After the Warm-Up, the TT, the TTE Test, and the Cooldown When Wearing Compression (COMP) or Control (CON) Garments

	HR,[a] beats/min		BLa, mmol/L		RPE (6 to 20)		TS (−4 to 4)		TC (1 to 7)	
	COMP	CON	COMP	CON	COMP	CON	COMP	CON	COMP	CON
Rest	62 (6)[b]	67 (15)	1.49 (0.29)[c]	1.42 (0.19)	—	—	0 (−1 to 1)	0 (−1 to 1)	4 (3 to 5)	4 (4 to 5.5)
Post-warm-up	152 (9)[b]	157 (6)	2.02 (0.21)	2.04 (0.41)	11 (8.5 to 12)	11 (10 to 14)	2 (2 to 3)	2 (1 to 4)	6 (5 to 7)	6 (4 to 7)
Post-TT	186 (5)[b]	188 (5)	10.76 (1.80)	9.83 (1.97)	19 (15 to 20)	19 (17 to 19)	4 (3 to 4)	4 (2 to 4)	7 (6 to 7)	6 (6 to 7)
Post-TTE	188 (7)	189 (5)	13.36 (2.57)[c]	12.31 (2.42)	19 (18 to 20)	19 (18 to 20)	4 (3 to 4)	4 (3 to 4)	6 (6 to 7)	6 (6 to 7)
Post-cooldown	—	—	8.56 (3.09)[b]	8.05 (2.89)	—	—	—	—	—	—

Abbreviations: BLa, blood lactate; HR, heart rate; RPE, rating of perceived exertion; TC, thermal comfort; TS, thermal sensation. TT, time trial; TTE, time-to-exhaustion test.
[a] n = 4 for heart rate data. [b] Moderate effect size ($d > 0.5$) versus CON. [c] Small effect size ($d > 0.2$) versus CON.

As shown in Table 1, there were no significant differences in HR, BLa concentration, RPE, TS, or TC scores between COMP and CON ($P > .05$). However, there were moderate effect sizes for the HR responses at rest ($d = 0.51$), post warm-up ($d = 0.65$), and post TT ($d = 0.50$), as well as small to moderate effect sizes for BLa concentration at rest ($d = 0.29$), post TTE ($d = 0.42$), and post cooldown ($d = 0.50$). Postexercise muscle soreness scores were not significantly different after 8 min ($P = .18$), 24 h ($P = .46$), or 48 h ($P > .99$) for COMP (8 min: 0 [0–3]; 24 h: 1 [0–4.5]; 48 h: 1 [0–4]) versus CON (8 min: 1 [0–3]; 24 h: 1 [1–5]; 48 h: 1 [0–3]).

Discussion

This study has shown that wearing commercially available upper- and lower-body compression garments during XC roller-skiing had no statistically significant effect on either TT or TTE performances. Moreover, there were no significant differences in the physiological (HR or BLa concentration) or subjective (RPE, TS, TC, or muscle soreness) responses. However, COMP was shown to elicit a small beneficial effect on TT and TTE test performances and a moderate effect of a lowered HR at rest, post warm-up, and post TT. This latter finding is consistent with previous research showing a mild reduction in HR during submaximal roller-skiing with the use of whole-body compression.[3]

Skattebo and Losnegard[12] have shown that the threshold for the smallest worthwhile difference in biathlon skiing performance is 0.82% and 0.97% for men and women, respectively. They also suggested that intervention strategies should aim to improve performance by ~2% to 3%, due to race variability.[12] In this study, TT performance was improved by 2.2% (4.3%) in COMP versus CON, and while this difference was not significant, 4 out of the 7 athletes demonstrated worthwhile improvements of ≥2% in COMP. Of these 4 athletes, a small improvement in TTE test performance was demonstrated by 1 athlete (see Figure 1). By contrast, no athlete performed worse in both the TT and TTE test. These findings suggest that there may be a beneficial effect of wearing COMP during biathlon competitions for at least some individuals.

It is worth noting that a placebo effect may have been present in this study, as blinding was not possible. In addition, the laboratory temperature was significantly warmer than would be experienced during winter-biathlon racing on snow, thereby limiting the real-world application of this findings. It is possible that COMP would elicit further benefits in cold environments, due to increases in skin temperature that have previously been reported with compression garments.[1] This possibility requires further investigation.

Practical Applications

Small beneficial effects may result from wearing whole-body compression garments during maximal XC skiing performance, albeit in individual cases. It is recommended that elite athletes test compression clothing under simulated race conditions prior to competition.

Conclusion

Despite no statistically significant differences in performance and physiological or subjective responses during a XC skiing TT or TTE test, wearing upper- and lower-body compression garments may have small but worthwhile beneficial effects on maximal XC skiing performance for some individuals.

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