Enhanced Cycling Time-Trial Performance During Multiday Exercise With Higher-Pressure Compression Garment Wear

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Abstract

Purpose: Compression garments are widely used as a tool to accelerate recovery from intense exercise and have also gained traction as a performance aid, particularly during periods of limited recovery. This study tested the hypothesis that increased pressure levels applied via high-pressure compression garments would enhance "multiday" exercise performance. *Methods:* A single-blind crossover design, incorporating 3 experimental conditions—loose-fitting gym attire (CON), low-compression (LC), and high-compression (HC) garments—was adopted. A total of 10 trained male cyclists reported to the laboratory on 6 occasions, collated into 3 blocks of 2 consecutive visits. Each "block" consisted of 3 parts, an initial high-intensity protocol, a 24-hour period of controlled rest while wearing the applied condition/garment (CON, LC, and HC), and a subsequent 8-km cycling time trial, while wearing the respective garment. Subjective discomfort questionnaires and blood pressure were assessed prior to each exercise bout. Power output, oxygen consumption, and heart rate were continuously measured throughout exercise, with plasma lactate, creatine kinase, and myoglobin concentrations assessed at baseline and the end of exercise, as well as 30 and 60 minutes postexercise. *Results:* Time-trial performance was significantly improved during HC compared with both CON and LC (HC = 277 [83], CON = 266 [89], and LC = 265 [77] W; $P < .05$). In addition, plasma lactate was significantly lower at 30 and 60 minutes postexercise on day 1 in HC compared with CON. No significant differences were observed for oxygen consumption, heart rate, creatine kinase, or subjective markers of discomfort. *Conclusion:* The pressure levels exerted via lower-limb compression garments influence their effectiveness for cycling performance, particularly in the face of limited recovery.

Numerous activities including, but not limited to, cycling require the completion of repeated bouts of intense exercise on consecutive days (eg, Tour de France), challenging the athlete to produce maximal efforts repeatedly in the face of limited recovery. As such, there is growing interest in strategies that accelerate recovery and improve performance, with numerous prophylactic and therapeutic interventions used, including compression garments (CG).(1–6) CG are frequently used to aid recovery and as a potential performance-enhancing tool, during and following bouts of strenuous exercise. Conceptually, the use of CG originates from clinical practice, where their use has been reported to effectively treat inflammatory conditions, such as lymphedema(7) and hypertrophic scar healing.(8,9) However, the ergogenic effects of CG on indices of exercise recovery and athletic performance are equivocal.(2,10) Indeed, the mechanisms underpinning any reported effects of CG have yet to be fully elucidated, but may involve enhanced blood flow velocity,(11,12) increased arterial perfusion,(13) reduced muscle oscillation,6 and attenuation of muscle swelling by facilitating lymphatic drainage and offsetting increases in osmotic pressure.(14) Indeed, this apparent enhanced blood flow observed with CG is comparable to that following thermoneutral, cold, and contrast water therapy.(15)

Nevertheless, the efficacy of CG as a recovery tool has been extensively studied, often in the context of exercise-induced muscle damage (EIMD).(16–18) By contrast, the effects of CG as a performance tool in the context of multiday exercise performance is relatively unknown. Indeed, few studies have investigated the effects of CG on recovery and performance during “accustomed” exercise that elicits minimal EIMD, similar to that observed during competitive multiday events.(5,19–21) Furthermore, a number of these previous studies assessed the efficacy of CG using indices of muscle function, which may not directly translate into alterations in endurance performance, per se. To our knowledge, only one study(20) has investigated the effects of CG on subsequent exercise performance to replicate a multiday event. The authors reported that 40-km cycle time trial (TT) performance was significantly improved following CG use compared with a control garment. However, importantly, the optimal degree of pressure exerted by CG has yet to be established. In addition, although a recent study has reported enhanced recovery following running exercise with CG between endurance exercise bouts (separated by 24 h), it is pertinent to note that running economy and a number of other physiological outcome measures were tracked, and thus, performance, per se, was not reassessed.(21)

The degree of compression exerted in previous studies utilizing CG has invariably been reported.(3,22–24) Indeed, studies that do report pressure levels of CG are likely dictated by a product of the garment’s type and size, rather than a prescribed degree of pressure, per se.(25) This is despite numerous clinical studies proposing a meaningful interaction between the level of compression applied and the ensuing physiological impact,(1,26,27) while others oppose this notion.(28) Therefore, quantifying the optimal levels of pressure from CG for athletic purposes may be an important consideration for its application in sporting performance and requires further attention.

The purpose of this study was, therefore, to assess the effects of varying levels of compression applied via lower-limb CG on multiday cycling performance at typical levels of EIMD associated with multiday exercise events. We hypothesized that, compared with a CG with lower compression levels and loose-fitting gym attire, a high-pressure garment would significantly improve performance during consecutive-day aerobic cycling exercise.

Methods

Participants

A total of 10 trained,(29) university-level male cyclists (mean [SD]; age 21 [2] y, height 1.78 [0.05] m, body mass 71 [11] kg, and VO2max 55 [10] mL/kg/min) provided written, informed consent to participate in the present study, which was approved by the University of Birmingham ethics committee. After the experimental design, associated risks, and potential benefits were explained, all participants gave their written consent. The participants were nonsmokers and were not users of any performance-enhancing supplements prior to the study initiation. The participants were asked to visit the laboratory in a rested, euhydrated state, having abstained from any strenuous activity for 24 hours prior to arrival. The participants had also abstained from caffeine and alcohol consumption for 6 and 24 hours, respectively. All tests were performed at a similar time of day (±2 h).

Experimental Design

The participants were required to report to the laboratory on 8 occasions over a 4- to 6-week period. All exercise tests were performed on a stationary cycle ergometer (Lode Excalibur Sport; Lode, Groningen, The Netherlands). During the first trial, the participants completed a ramp incremental exercise test for determination of peak oxygen uptake (VO2 peak), maximum aerobic power output, and gas exchange threshold (GET). Initially, the participants were familiarized to each of the performance trials employed during the study (described below) on at least 2 occasions until the time to complete the TT was <1%. Following completion of these visits, the participants returned to the laboratory on 6 occasions, divided into 3 blocks of 2 consecutive testing days. Each block replicated the same design, but under 3 experimental conditions: wearing loose-fitting gym clothing (CON), a low-pressure CG (LC), or a high-pressure CG (HC) (see "Compression Garments" section). Each experimental trial consisted of a high-intensity protocol (day 1) and an 8-km cycling TT (day 2, described below), completed at the same time of day (±2 h). Upon completion of day 1, the participants were provided with a 24-hour meal plan and instructions to wear the specific garment until the completion of day 2 testing. Dietary provision was standardized for each trial, using a revised Harris–Benedict equation.(30) The participants selected 1 of 2 energy-balanced meal options prior to the study commencement, which was replicated during each testing block. The meal plans equated to ∼31% protein, ~56% carbohydrate, and ∼13% fat. A 7-day washout period separated each of the 3 experimental conditions. Throughout, the participants were encouraged to maintain their habitual training routine and lifestyle. The participants were allocated to each experimental condition in a randomized crossover experimental design. The participants were naive to the specific experimental hypotheses. An overview of the experimental trials is depicted in Figure 1.

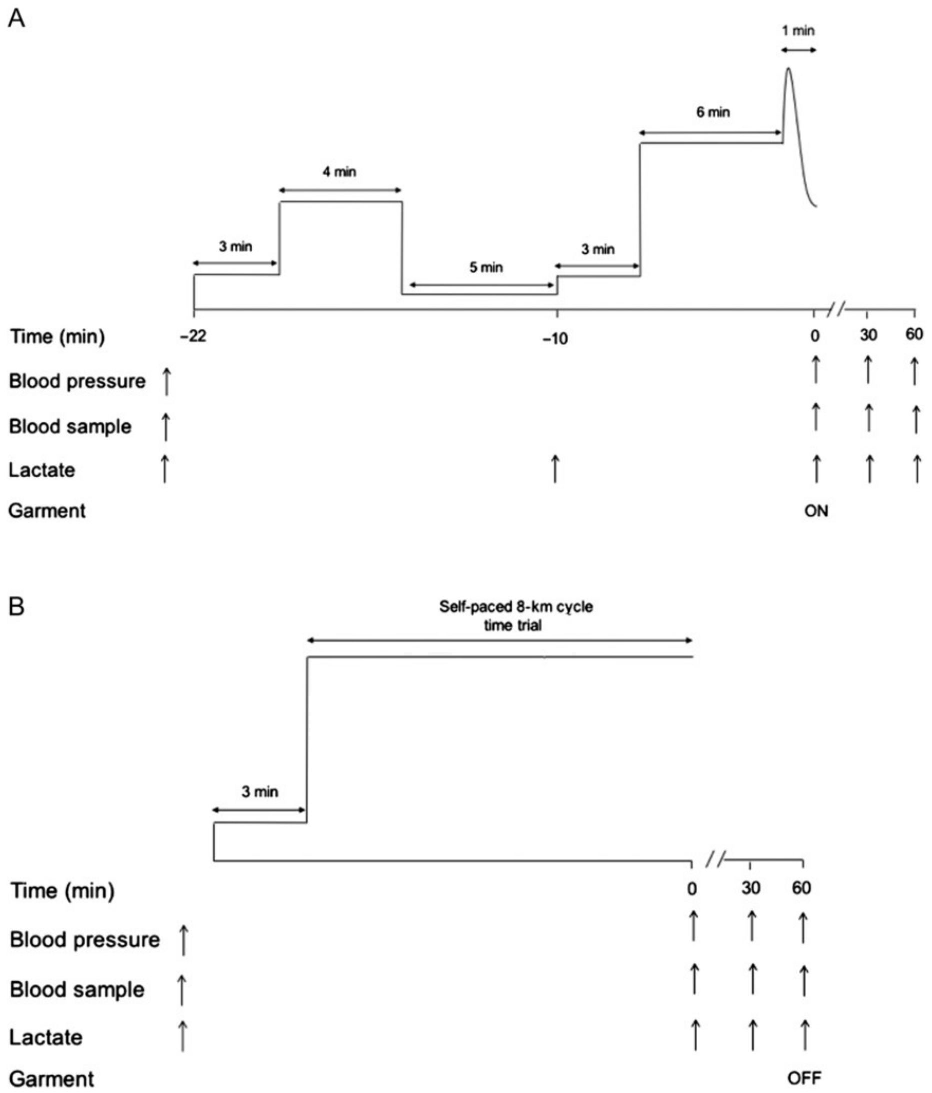

Figure 1

—Schematic depicting the 2 exercise trials implemented throughout the study. The high-intensity trial (panel A) was performed on day 1, and the time trial (panel B) was completed approximately 24 hours later, on day 2. The garment was not removed throughout the 24-hour period. Specifically, garments were applied immediately following the completion of a high-intensity cycling protocol on day 1 (incorporating severe-intensity exercise and a 60-s sprint finish) and removed following the completion of an 8-km cycling time trial on day 2. Assessment of blood pressure, markers of muscle damage, and plasma lactate were assessed at the corresponding time points.

Preliminary Trials

The first laboratory visit entailed the completion of a ramp incremental cycle test. Prior to the test initiation, the cycle ergometer was configured to allow for replication in subsequent visits. Exercise commenced with a 3-minute “baseline” cycle at 20 W, after which the work rate increased linearly by 30 W/min until the limit of tolerance. The participants were instructed to cycle at a preferred cadence between 70 and 90 RPM, and the test was terminated at the point at which they were unable to maintain 60 RPM for >10 seconds. Breath-by-breath pulmonary gas exchange was collected continuously. The baseline and end-exercise $\dot{V}O_2$ were calculated as the mean $\dot{V}O_2$ over the preceding 60 seconds and final 30 seconds of each transition. The GET was determined via (1) an increase in end-tidal $\dot{V}O_2$ tension with no fall in end-tidal $\dot{V}CO_2$ tension and (2) a disproportionate increase in $\dot{V}CO_2$ ($\dot{V}CO_2$) production from visual inspection of $\dot{V}O_2$ and $\dot{V}CO_2$. Subsequently, the work rate at 90% of GET (moderate-intensity exercise) and 70% Δ (work rate at GET plus 70% of the difference between the power output at GET and $\dot{V}O_{2peak}$: severe-intensity exercise) were calculated. In addition, a linear factor equivalent to 65% Δ was calculated, as described below, for the determination of cycling resistance during the 8-km TT.

Experimental Trials

Upon arrival at the laboratory, the participants were instructed to rest in a seated position for 10 minutes. Subsequently, blood pressure was measured using an automated sphygmomanometer (Omron 705CP; Omron Matsusaka Co, Kyoto, Japan). Thereafter, an initial blood sample was drawn from an indwelling catheter via an antecubital vein. Throughout the trials, blood samples were drawn into K2 ethylenediaminetetraacetic acid and SST II Vacutainers (BD, Plymouth, United Kingdom). For each experimental condition (CON, LC, and HC), 2 exercise protocols were performed: a high-intensity protocol on the initial visit (ie, day 1) and an 8-km cycling TT during day 2. The high-intensity trial was composed of 2 bouts of exercise: the first at a moderate intensity (90% GET) and the second at a severe-intensity work rate (70% Δ GET). Each bout commenced with 3 minutes of baseline cycling at 20 W before an abrupt transition to the respective workload. Five minutes of passive recovery separated the cycling bouts. Immediately upon completion of the second bout, the participants completed a 60-second all-out sprint. Resistance during the "sprint" was set using the linear mode of the ergometer such that, upon reaching their preferred cadence, the participants would achieve a power output equivalent to 50% of the difference between GET and $\dot{V}O_{2peak}$

(Linear factor = 50% Δ power output/preferred cadence2). Following a 5-second countdown, the participants were instructed to reach their peak power as quickly as possible and sustain a maximal effort for the duration, utilizing a protocol similar to our previous work.(31) Standardized verbal encouragement was provided throughout; however, the participants were blinded to any potential indicators of performance. Upon completion, an immediate and 60-minute postexercise blood sample was drawn. The experimental measurement procedures adopted during day 1 were replicated 24 hours later. However, upon arrival, subjective questionnaires were completed, which assessed muscle soreness, fatigue, and sleep quality using a 10-point visual analog scale. Additional questions regarding garment comfort, irritability, and fit were included to assess the suitability of CG. For the 8-km cycling TT, following a passive 90-second baseline rest period, resistance on the pedal transitioned to the linear mode, as discussed above. The participants were instructed to complete the selected distance as quickly as possible, utilizing their desired pacing strategy. No visual time feedback was provided during the trial; however, a verbal signal was given on completion of 4 and 6 km, respectively.

Measurements

Throughout all trials, pulmonary gas exchange and ventilation were measured continuously breath by breath, with participants wearing a nose clip and breathing through a low-resistance, dead space triple turbine assembly (Jaeger, Triple V; Viasys Healthcare GmbH, Hoechburg, Germany). Inspired and expired gas concentration and volume signals were continuously sampled at 100 Hz, using an infrared and paramagnetic analyzer (Vyntus CPX; CareFusion, Höchberg, Germany). Prior to each test, the turbine volume transducer was calibrated using a 3-L syringe (Hans Rudolph, Kansas City, MO), and the gas analyzers were calibrated to gases of known concentration. Heart rate was measured throughout all trials via a Polar A300 heart rate sensor (Polar Electro, Kempele, Finland). Plasma glucose was analyzed via a Biosen C-Line (EKF Diagnostic, Barleben, Germany). Plasma lactate concentrations were determined using a semi-automatic ILab 650 analyzer (Instrumentation Laboratory, Bedford, MA) and commercially available kits (Randox Laboratories Ltd, County Antrim, United Kingdom). Plasma creatine kinase and myoglobin were analyzed using a Cobas 6000 E-module (Roche Diagnostics GmbH, Mannheim, Germany).

Compression Garments

The lower-limb garment manufacturer differed between the HC (ReForm leggings; Python Performance Ltd, Birmingham, United Kingdom) and LC trials (Sub RX; Sub Sports, Keighley, United Kingdom). The manufacturers' sizing recommendations were used to select an appropriately sized garment for each participant. The garments were worn from within 10 minutes of exercise completion during day 1 until departure from the laboratory the following day 2. The compression levels were measured using an air-pack sensor (PicoPress; Microlab Elettronica, Ponte San Nicolo, Italy) placed between the skin and garment at the distal hem (3-cm superior to distal hem), maximum calf, mid-thigh (50% between patella and great trochanter), head of femur, and posterior superior iliac spine.(23)

Statistical Analysis

A 2-way (time × condition) repeated-measures analysis of variance was employed to assess between-garment (CON, LC, and HC) differences in blood pressure, plasma lactate and glucose, creatine kinase, plasma myoglobin, pulmonary $\dot{V}O_2$, and exercise performance indices. Where the analysis of variance revealed a significant interaction effect, post hoc tests were completed using Fisher LSD with statistical significance accepted as $P < .05$. For calculation of the effect size, partial eta-squared (η^2) was used for omnibus tests. Cohen d was used to calculate the effect size for paired t tests and post hoc comparisons. All the examined variables were normally distributed. For all tests, the results were considered statistically significant when $P < .05$. The data are presented as mean (SD) unless otherwise indicated. All statistical analyses were conducted using IBM Statistical Package for the Social Sciences (version 25; IBM Corp, Armonk, NY).

Results

The participants attained a $\dot{V}O_2peak$ of 3.91 (0.72) L/min (55 [10] mL/kg/min) and a peak power output of 367 (76) W during the incremental ramp test. The work rate applied during the high-intensity trial on day 1 was 277 (63) W. There were no differences in pulmonary $\dot{V}O_2$ at the baseline or end exercise during the TT between the 3 experimental conditions (all $P > .05$, $\eta^2 < .010$). The pressure levels (mean [SD]) in the LC garment were measured at 7 (3), 7 (3), 5 (2), 5 (2), and 5 (1) mm Hg and for the HC were 11 (3), 15 (3), 10 (3), 8 (2), 6 (1) mm Hg, respectively, at the distal hem (3-cm superior to distal hem), maximum calf, mid-thigh (50% between patella and great trochanter), head of femur, and posterior superior iliac spine, respectively.

TT Performance

The TT performance during HC was improved by ∼6% compared with CON. Specifically, there was a significant main effect for condition on TT performance (CON = 1010 [364], LC = 988 [319], HC = 947 [304] s, P = .04, η2 = .24, Figure 2). Post hoc analysis revealed that the average work rate was greater in HC (277 [83] W) compared with CON (265 [77] W, P = .03, d = 0.15) and LC (266 [89] W, P = .03, d = 0.13), with no difference between LC and CON (P = .91, d = 0.01). The time-to-completion for HC was significantly lower compared with CON (P = .040, d = 0.19) and LC (P = .01, d = 0.13), with no difference between LC and CON (P = .33, d = 0.06; Figure 2). When compared with LC, the improvement in mean group performance was evident in 8 out of 10 participants, ranging from a −15.1% to a +0.9% change in time to complete the 8-km TT (Figure 2).

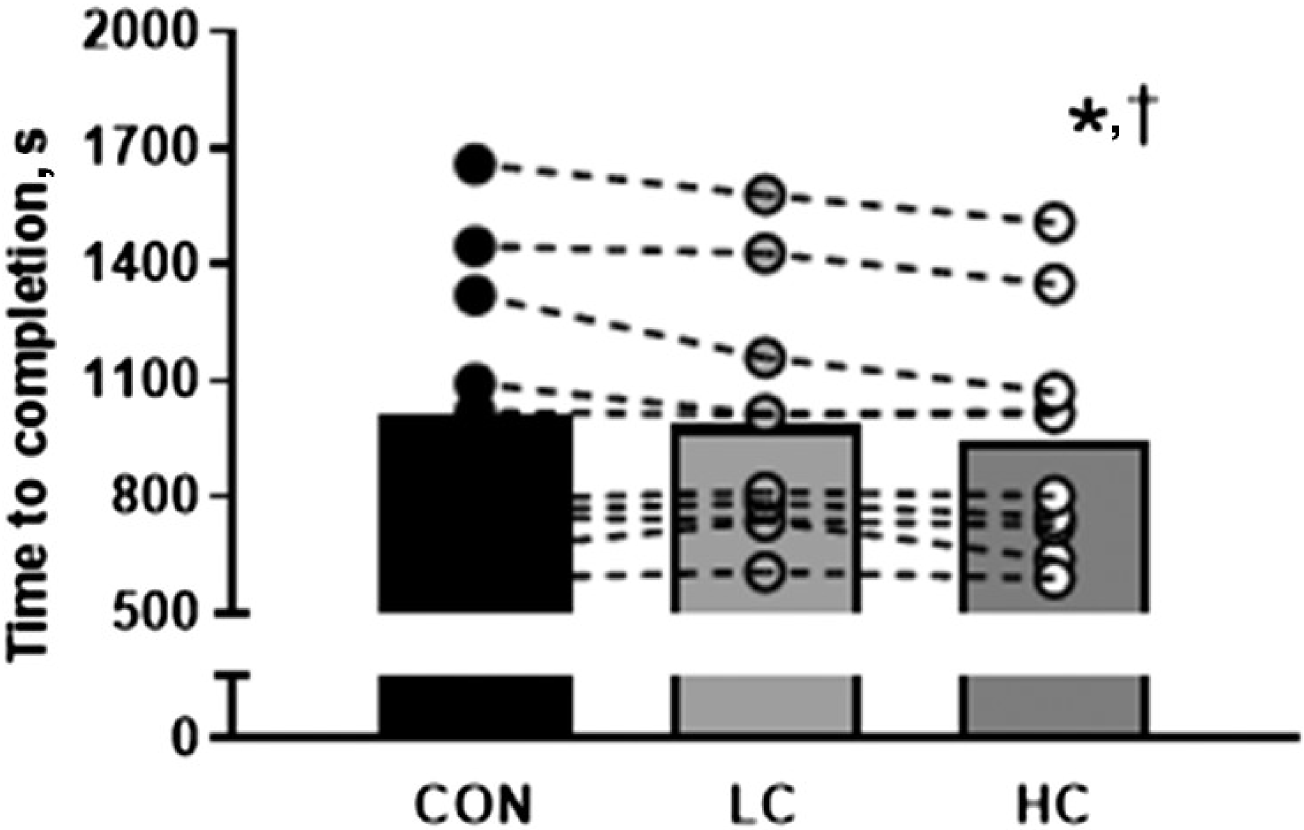

Figure 2

—Mean (SD) for 8-km TT performance. Individual responses in each condition are shown by the black, gray, and clear circles, respectively, and linked with dashed lines. CON indicates control; HC, high-pressure compression garment; LC, low-pressure compression garment; TT, time trial. *Significantly lower mean time between HC (clear circles) and CON (black circles). †Significantly lower mean time between HC and LC (gray circles). The improvement in mean group performance was evident in 8 out of 10 participants, ranging from a −15.1% to a +0.9% change in time to complete the 8-km TT.

Blood Markers and Subjective Soreness

The group mean plasma lactate for both trials for all conditions are shown in Figure 3. A significant main effect was reported for plasma lactate on day 1 (P = .04, η2 = .120; Figure 3A) and day 2

(P = .047, η2 = .19; Figure 3B) between conditions. No significant effects were observed for blood glucose (all Ps > .05). There were no significant main effects reported for myoglobin at any time points on either of the experimental trial days between conditions (all Ps > .05; Figure 4B and 4D). Conversely, a main effect of time was observed for creatine kinase during day 1 (P < .01; Figure 4A) and day 2 exercise (P < .001; Figure 4C). Post hoc analysis revealed there to be a significant difference between the immediate post high-intensity trial (CON = 192 [62], LC = 312 [103], and HC = 240 [76] IU/L) and the 60-minute post-high-intensity trial (CON = 264 [101], LC = 241 [116], and HC = 302 [96] IU/L,P = .04, d > 1.11). Prior to the TT visits, all participants reported minimal muscle soreness, averaging 2 (1) cm on the visual analog scale, irrespective of the condition (all Ps > .05). Furthermore, irrespective of the trial condition, participants reported no differences in sleep quality, fatigue, and/or discomfort, as assessed by subjective questionnaires (all Ps > .05)

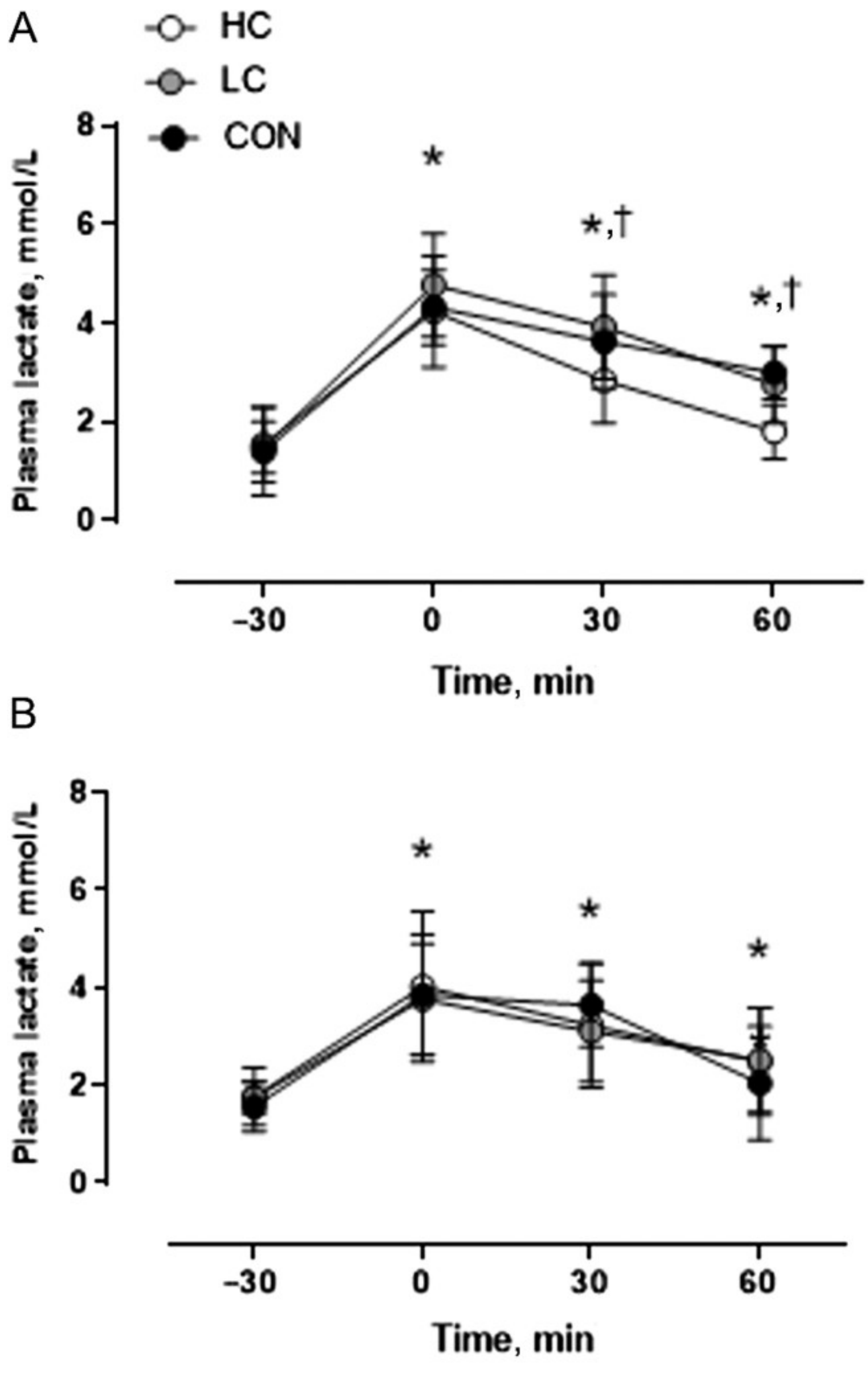

Figure 3

—Plasma lactate on day 1 (A) and day 2 (B) for the HC (clear circles), LC (gray circles), and CON (black circles) conditions. Values are presented as mean (SD). CON indicates control; HC, high-pressure compression garment; LC, low-pressure compression garment. *Significant difference reported between time points. †Significance between HC and CON.

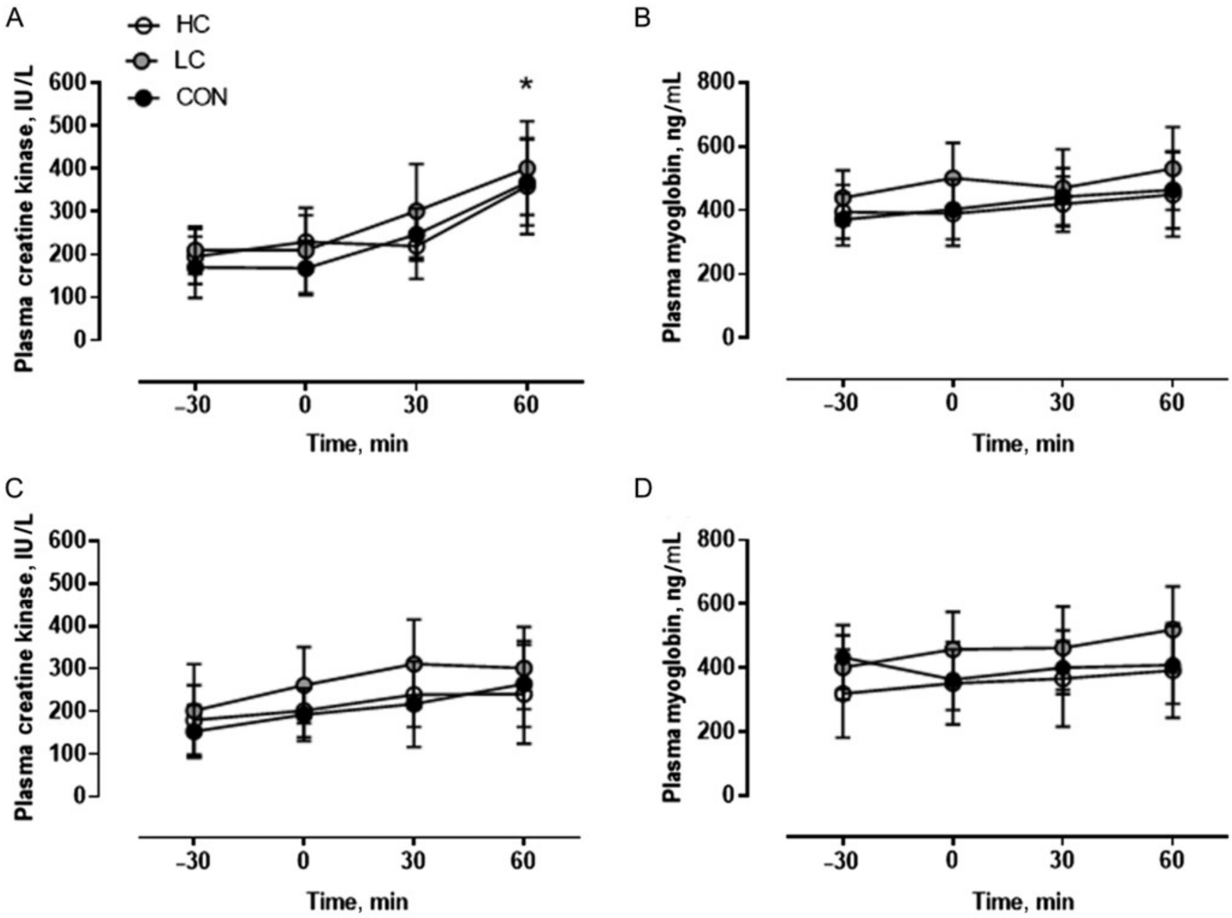

Figure 4

—Plasma creatine kinase and myoglobin on day 1 (A and B, respectively) and day 2 (C and D, respectively) for the HC (clear circles), LC (gray circles), and CON (black circles) conditions. Values are presented as mean (SD). CON indicates control; HC, high-pressure compression garment; LC, low-pressure compression garment. *Significant difference reported between time points.

Blood Pressure and Heart Rate

There were no significant main effects for average (CON = 175 [11], LC = 173 [11], and HC = 175 [8] beats per minute; $P = .84$, $\eta 2 = .13$) or peak (CON = 189 [8], LC = 190 [7], and HC = 189 [10] beats per minute, $P = .85$, $\eta 2 = .01$) heart rate during either trial. In addition, there were no differences in resting systolic blood pressure (CON = 138 [14], LC = 137 [12], and HC = 140 [14] mm Hg, $P = .86$, $\eta 2 = .11$; Figure 5). However, a significant main effect was observed for resting diastolic blood pressure (DBP; CON = 74 [6], LC = 73 [7], and HC = 66 [5] mm Hg, $P < .01$, $\eta 2 = .32$; Figure 5) and mean arterial pressure (MAP; CON = 95 [9], LC = 95 [6], and HC = 86 [4] mm Hg, $P = .04$, $\eta 2 = .34$) following 24 hours of wear time. Post hoc analysis revealed that DBP was higher in both the LC ($P < .01$, d = 1.35) and CON (P < .01, d = 1.54) compared with the HC condition, with no difference reported between the LC and CON conditions (P = .77, d = 0.12). Similarly, MAP was significantly lower during HC compared with LC (P < .01, d = 1.40) and CON (P < .01, d = 1.85).

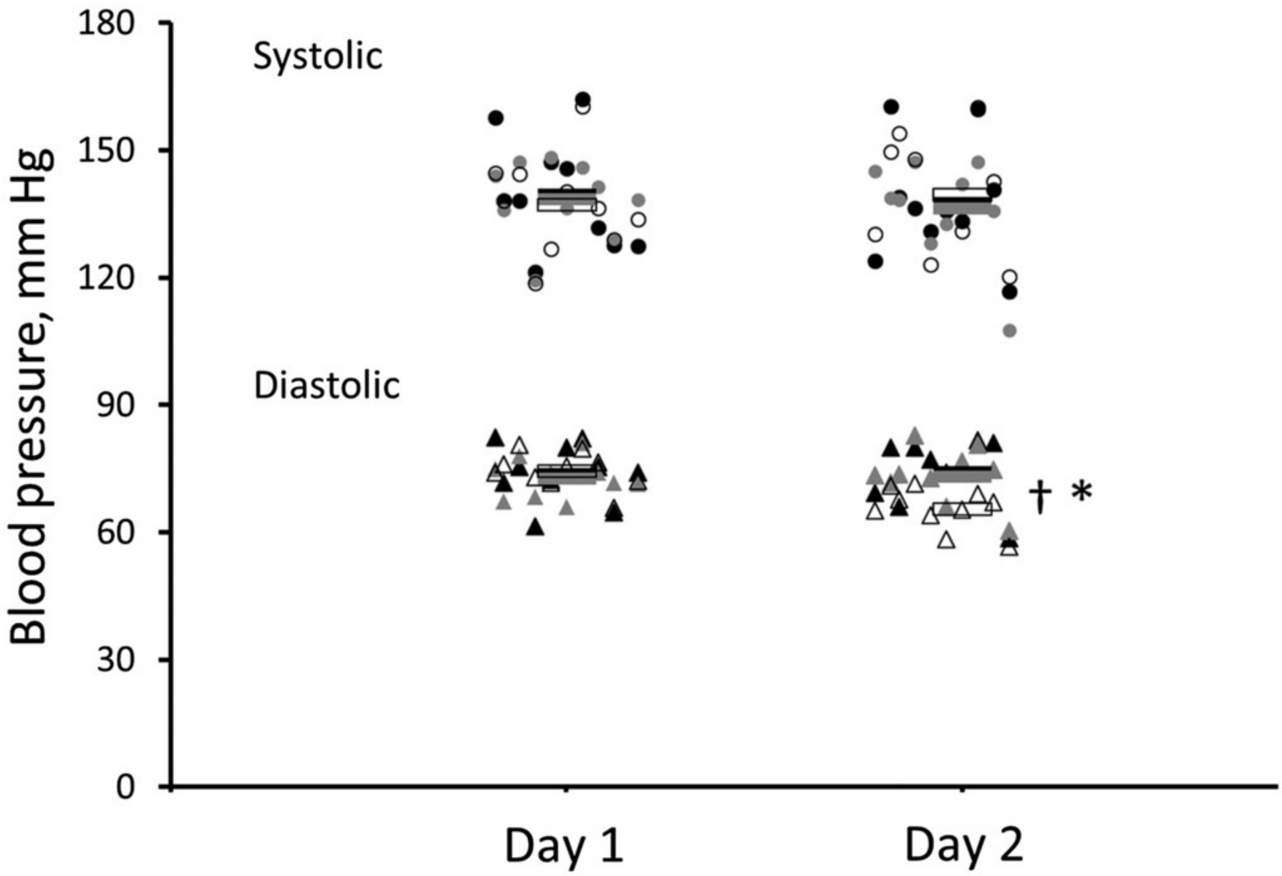

Figure 5

—Individual systolic (circles) and diastolic (triangles) blood pressures measured prior to the high-intensity trial on day 1 and prior to the time trial on day 2 for HC (clear), LC (gray), and CON (black) conditions. The solid horizontal bars represent the mean value of each respective condition for systolic and diastolic blood pressure. CON indicates control; HC, high-pressure compression garment; LC, low-pressure compression garment. †Significant decrease in blood pressure between HC and CON. *Significant decrease between HC and LC.

Discussion

The primary aim of the present study was to examine the effects of varying levels of compression, applied via lower limb CGs, on multiday endurance cycling performance. Specifically, in agreement with our hypothesis, we demonstrated that 8-km TT performance was significantly improved with higher compression levels compared with a lower-level CG and loose-fitting clothing controls by ~6%. However, with the potential exception of a reduction in DBP and MAP, no physiological or subjective mechanistic explanations were present.

A consensus regarding the effects of CGs on exercise performance, particularly during multiday exercise, is lacking. Indeed, few studies have implemented a control condition and/or have only investigated the effects of wearing HC on acute exercise performance(1,21) and recovery of muscular function using maximal voluntary contraction-based tests, which may not share a close relationship with exercise performance, per se.(26) To our knowledge, only one other study has attempted to examine the effects of HC on consecutive-day cycling aerobic performance.(20) The present results were consistent with those previously reported, a 5.5% and 4.4% improvement in TT performance during the higher CG compared with the CON and LC conditions, respectively. In contrast, we observed no significant performance improvements for LC when compared with CON. Furthermore, in agreement with the present investigation, Mizuno et al(21) observed enhanced recovery of running economy and a number of other outcome measures (ie, jump performance, a number of blood markers, leg circumference, subjective feelings of fatigue) with 24-hour use of CG following a bout of endurance exercise running, which would likely result in enhanced exercise performance. Taken together, recent studies, combined with the present investigation, provide growing support of a potential ergogenic effect of wearing CG for multiday exercise performance.

By controlling dietary intake, registering fluid intake, and including both LC and CON conditions, we attempted to mitigate for any of these potentially confounding factors reported in previous studies. Nonetheless, it is difficult to fully account for a possible effect of LC when compared with the effect of HC, with previous research demonstrating other effects, such as enhanced motor control and altered autonomic function.(32) However, the participants were unable to subjectively, consistently, or, indeed, correctly report which garment was “tightest,” likely due to other proprioceptive factors, such as comfort and breathability, as highlighted in the questionnaires. Consequently, we can assume the comparison between LC and HC negates any placebo effect and, in turn, supports the recent results of Hill et al,(26) which demonstrated improvements in performance only with higher levels of compression.

The underlying mechanistic explanation for the observed performance improvements with the use of HC remains elusive. Reduction in venous blood pooling and muscle swelling due to external muscular compression have been suggested as important factors in facilitating recovery and performance enhancement with CGs.(14) However, the mechanistic explanation for improved performance appears to be somewhat more subtle. Indeed, while the precise mechanisms for a possible ergogenic effect during exercise are not well understood, enhanced muscle oxygenation,(33) tissue oxygen saturation,(34) and postexercise lactate removal(35) have all been suggested as contributing factors. Furthermore, Doan et al(36) suggests that wearing CG during running appeared to have a “protective” effect on muscle fibers, potentially by reducing muscle oscillations. This concept has recently been supported by advancements in biomechanical research associated with CGs. Indeed, our data on improved performance with CGs are in agreement with a recent study that investigated the effects of high-pressure-level CG on muscle displacement, soft tissue vibration, and muscle activation during submaximal running.(37) Specifically, the authors reported positive reductions in muscle displacement, and soft tissue vibration, alongside an increase in muscle activation.(38) These results suggest that a greater level of compression may result in increased muscle activation and reduction in muscle damage. More research in the field is required; however, interestingly, while the ergogenic effect of CG is not a consistent finding across all types of exercise, it does appear to be beneficial for cycling, suggestive that the mechanism may be intrinsically linked to the mode of exercise.(39,40)

In the current study, while we found a time effect for plasma lactate, no other noteworthy differences were observed between conditions during the TT to tease out some of the potential mechanisms for such an improvement in performance. However, plasma lactate was significantly lower for the HC group compared with CON and LC at the +30- and +60-minute posthigh-intensity trial (ie, day 1). Although it is pertinent to note, as expected, that we did not observe elevated levels of EIMD on day 2, as evidenced via minimal changes to various blood markers, we would not expect to evoke significant muscle damage during accustomed and/or exercise composed of minimal eccentric contractions.41 Nevertheless, the garments were applied within 10 minutes of end exercise (day 1), potentially driving an acute effect of compression on the removal of intramuscular metabolites, which may have important implications for consecutive-day exercise performance. Nevertheless, sustained effects over the full 24-hour period may have been diminished by a material stretch occurrence. Reassessment of the compression levels applied at multiple time points during this phase may have, therefore, provided further insight into the potential effects and mechanisms that support performance improvement with higher-pressure CG during consecutive-day exercise performance.42 Therefore, we are unable to distinguish between whether the improvements in performance were due to the use of HC during recovery, performance, or both. However, it has been suggested that any potential benefit of CG use during cycling appears to be more closely associated with the effects primarily during periods of relative recovery, rather than offering a significant “immediate” performance benefit.(15) In the present study, it may have been prudent to add another experimental condition, where the use of HC was refrained during the 24-hour recovery period, and thus, restricted to being worn during the day 2 exercise task, to answer this important question.

Interestingly, we observed a 12% and 5.5% decrease in DBP and MAP, respectively, from the baseline to pre-TT in HC (ie, ∼22 h after HC was applied). Conversely, no significant differences in blood pressure were observed with either CON or LC. The present results are not in agreement with those presented by de Glanville et al,(20) who reported a decrease in blood pressure following the removal of CGs. The authors speculated that, upon removal, any elevation in pressure dropped immediately, resulting in a relative decrease in venous return and peripheral resistance.(20) Interestingly, others have investigated the effects of CGs on hemodynamics, reporting no significant difference compared with loose-fitting breeches.(43) However, it must be noted that measurements on day 2 of the present study were administered with the respective garment in situ, which may have directly influenced blood pressure. It is widely accepted that cardiac output increases markedly during exercise to accommodate an upsurge in blood flow and oxygen delivery.(10) Concurrently, regional vasodilation of active tissues and vasoconstriction of nonessential tissue arterioles occurs. Due to these physiological events, it is common for systolic blood pressure to increase; however, postexercise hypotension is widely documented following this blood pressure proliferation.(11) We suspect that the higher compression levels may contribute to a continued arterial return, increasing venous return and stroke volume, and consequently, increasing cardiac output.(39) This would explain the slight increase in systolic blood pressure. Nevertheless, further research directly measuring alterations in stroke volume, cardiac output, and heart rate are required to confirm these speculations.

Practical Applications

This study demonstrated that lower-limb garments with higher levels of compression markedly improved 8-km TT performance in trained cyclists, following a prior-day exhaustive exercise trial, compared with lower-pressure garments and a loose-fitting control. These findings may have important implications for athletic populations competing in multiday aerobic-based events. Therefore, it is recommended that athletes consider incorporating high-pressure CGs into their daily routines during multiday performance events.

Experimental Considerations

Although the current investigation is consistent with previous studies reporting an ergogenic effect of CG on endurance exercise performance, it is acknowledged that a limitation of the study was that the participants wore the garments continuously from the end of the first day through to the end of the second day. Therefore, identifying whether any observed effects of CG were the result of enhanced recovery following the initial bout of exercise and/or improved exercise performance during the subsequent bout was not possible. Indeed, this limitation may have also influenced some of the baseline measures at the start of day 2 (ie, blood pressure, resting heart rate). In addition, while many control measures were incorporated into the study design to mitigate any other potential confounding factors during the 24-hour recovery period, the participants were not tracked and/or continuously monitored during this time; thus, we cannot confirm, with complete certainty, their adherence to the protocols.

Conclusion

In conclusion, higher compression levels applied via HC markedly improve multiday cycling TT performance compared with lower-pressure garments and loose-fitting clothing. These results support recent research highlighting the importance of the level of pressure applied on the effectiveness of CG on performance recovery. However, as any such physiological mechanism for an effect was absent, further research is required to confirm the mechanisms through which CGs enhance multiday exercise performance.

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