The Effects of Wearing Lower Body Compression Garments During a Cycling Performance Test

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Purpose: Compression garments have been commonly used in a medical setting as a method to promote blood flow. Increases in blood flow during exercise may aid in the delivery of oxygen to the exercising muscles and, subsequently, enhance performance. The aim of the current study was to investigate the effect of wearing lower body compression garments during a cycling test. Methods: Twelve highly trained cyclists (mean ± SD age 30 ± 6 y, mass 75.6 ± 5.8 kg, VO2peak 66.6 ± 3.4 mL · kg⁻¹ · min⁻¹) performed two 30-min cycling bouts on a cycle ergometer in a randomized, crossover design. During exercise, either full-length lower body compression garments (COMP) or above-knee cycling shorts (CON) were worn. Cycling bouts involved 15 min at a fixed workload (70% of VO2max power) followed by a 15-min time trial. Heart rate (HR) and blood lactate (BL) were measured during the fixed-intensity component of the cycling bout to determine the physiological effect of the garments. Calf girth (CG), thigh girth (TG) and perceived soreness (PS) were measured preexercise and postexercise. Results: COMP produced a trivial effect on mean power output (ES = .14) compared with CON (mean ± 95% CI 1.3 ±1.0). COMP was also associated with a lower HR during the fixed-workload section of the test (–2.6% ± 2.3%, ES = –.38). There were no differences between groups for BL, CG, TG, and PS. Conclusion: Wearing compression garments during cycling may result in trivial performance improvements of ~1% and may enhance oxygen delivery to the exercising muscles.

Keywords: time trial, blood lactate, blood flow

The use of compression garments and compression bandaging has been well documented in the medical literature as a method of treating circulatory disorders, predominantly through the prevention of venous stasis and the promotion of blood flow.¹ Given the efficacy of compression garments as a treatment in the medical setting, the use of compression garments in the athletic industry has become increasingly popular over the past decade.² Several commercial sportswear companies have made claims that the associated medical benefits can be applied in an exercise setting. Compression garments are thought to improve venous return through application of graduated compression to the limbs from proximal to distal.³ The garments exert pressure directly on underlying tissues, which is proposed to reduce the transmural pressure of arterioles, causing them to dilate, as well as redistributing blood from the periphery to the deep venous system, further aiding in an increase of blood flow back to the heart.⁵ In addition to improved blood flow, potential mechanisms that mediate performance gains when wearing compression garments appear to be related to a myriad of variables including enhanced proprioception,⁶ improved oxygen delivery and perfusion,⁴ improved heat tolerance,⁷ and reduced muscle oscillation during exercise.⁸

The use of compression garments in the sports-science literature seems to be more favorable toward its implementation as a recovery strategy rather than during exercise.² The research concerning the effects of wearing compression garments during exercise includes many conflicting findings, and the literature is fragmented due to the great heterogeneity among studies.² Some of the inconsistencies include the type, duration, and intensity of exercise; the performance assessments employed; the training status of participants; the type of garment worn; and the applied level of compression. While there are studies that both support and show no effect of wearing compression garments during exercise, we are not aware of any that have shown detrimental results on performance, suggesting that it is unlikely that compression garments will have an ergolytic effect. Furthermore, given the fact that some studies have shown both physiological and performance benefits when wearing compression garments,⁹–¹¹ it is possible that the garments used in studies that have reported no benefit may not have used an adequate level of compression in their garments to alter the physiology of their subjects.

While there appear to have been a greater number of research studies examining the effect of compression garments on jumping,⁶ sprinting,⁷ repeat sprints,¹²,¹³ and strength⁴ exercise tasks, there has been limited research focusing on the physiological and performance responses during endurance cycling. A small number of studies...
have investigated the use of compression garments on endurance running, with varying results. Bringard et al. reported significantly enhanced running economy during submaximal running in 6 trained subjects. They suggested that improvements in circulation and reductions in muscle oscillation when wearing compression garments may have promoted the observed economy improvements. However, these benefits to running performance may not translate to low-impact sports such as endurance cycling. While a few studies have evaluated the use of compression garments on recovery between cycling bouts, there has been limited research on the use of compression garments on physiological responses and performance during cycling. Scanlan et al. studied the effect of wearing compression garments during an incremental cycling test and a 1-hour time trial in 12 trained cyclists (mean VO2max = 55 mL·kg⁻¹·min⁻¹) and reported no significant benefit to performance. However, they suggested a possible benefit to both muscle-oxygenation economy and power output at anaerobic threshold (78% and 86% positive likelihoods, respectively) when wearing compression garments, indicating a trend toward a benefit in trained subjects. Burden and Glaister also examined the use of compression garments during an endurance-cycling test (30 min at 60% VO2max power + 10-km time trial) in trained athletes (VO2max = 50 mL·kg⁻¹·min⁻¹) and reported no significant performance benefit in the experimental trials. However, the effects of lower body compression garments in highly trained cyclists (rather than moderately to well-trained cyclists) remain largely unknown, as do the effects in endurance-cycling tests of shorter durations. More specifically, the application of compression garments to events lasting ~30 minutes has not yet been examined. Events of this duration may be applicable to certain track cycling events (eg, scratch race, points race) or cycling time trials over distances of 15 to 20 km, which are often common in cycling tour races.

Therefore, the aim of the current study was to investigate the effect of wearing lower body compression garments on performance during a 30-minute endurance-cycling test in highly trained cyclists. A further aim of the study was to determine various physiological and perceptual responses when wearing compression garments during the cycle test.

**Methods**

**Subjects**

Twelve highly trained male cyclists (mean ± SD age 30 ± 6 y, height 180 ± 5 cm, mass 75.6 ± 5.8 kg, VO2peak 66.6 ± 3.4 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 provide informed consent. The study was approved by the Australian Institute of Sport Research Ethics Committee.

**Design**

The current study involved subjects attending 5 separate testing sessions at our laboratory over a 3-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 power output (PPO) and VO2peak. After the incremental cycling test, subjects completed 2 full familiarization trials of the exercise sessions, separated by 2 days to minimize any learning effect. Unpublished reliability studies from our laboratory would suggest that the smallest worthwhile change for the current test protocol in highly trained cyclists after 1 familiarization session is ~1%. Two experimental trials were then performed in a randomized, crossover design separated by 3 days. To control any dietary variables, subjects completed a 24-hour food diary before 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 completing identical training in the 72 hours before testing on both occasions. Subjects were asked to refrain from strenuous exercise (<24 h) and caffeine intake (<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.

**Methodology**

Before the start of the study, the cycle ergometer (Lode, Groningen, Netherlands) was calibrated on a dynamic calibration rig using a first-principles approach by specialists at the Australian Institute of Sport. The incremental cycling test started at 150 W and increased in power output by 25 W every minute until volitional exhaustion was reached or the subject could no longer maintain a pedal cadence of >70 rpm. Cardiorespiratory metabolic variables were measured throughout the progressive exercise test using a fully automated indirect calorimetry system set at a 30-second sample rate (AIS, Belconnen, ACT, Australia). The analyzer was calibrated before each test using alpha gases of known concentration, according to the manufacturer’s instructions. During the progressive exercise test, each subject was encouraged to give a maximal effort. VO2peak was taken as the highest VO2 value recorded over 1 minute during the incremental test. PPO was determined using the following formula:

\[
\text{PPO} = W_{\text{com}} + (\tau/60 \times 25)
\]

where \( W_{\text{com}} \) is the power output for the last full workload completed, \( \tau \) 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, as used previously. The experimental trials involved subjects performing 2 identical exercise tasks separated by 3 days. The identical cycle-exercise task (EX) consisted of a 10-minute warm-up (2 min at each of the following intensities: 125 W, 150 W, 175 W, 200 W, 70% PPO), then 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. Including a period of fixed power output in a time-trial test is an effective way to examine and monitor differences in physiological variables over repeated trials, while also increasing the reliability of the test. During EX, subjects had access to time information and were required to produce as much work as possible in the time frame, but no other information was provided. Immediately after EX, a standardized cooldown was completed (5 min at 40% PPO). During the first trial, a carbohydrate beverage (Gatorade; 6% carbohydrate content) was supplied and consumption was recorded over the EX to replicate in the second trial. 

During EX, subjects were required to wear either lower body compression garments or above-knee cycling shorts. The compression garments used during EX in the current study were men’s full-length tights (2XU Elite compression tights, Hawthorn, VIC, Australia) made of 50- and 70-denier Lycra material. The garments ran from the superior aspect of the medial malleolus of the ankle to fractionally superior to the iliac crest. Each garment was fitted according to manufacturer’s guidelines using the subject’s height and body mass. While it was not measured in the current study, according to the manufacturer’s claims, the compression garments are said to exert graduated compression with an estimated pressure of ~18 mmHg at the medial malleolus decreasing to ~10 mmHg at the gluteus maximus. During EX in the control trial, subjects wore their own above-knee-length cycling shorts.

Blood lactate concentration was measured via a capillary fingertip sample and analyzed with a Lactate-Pro analyzer (Shiga, Japan). The test–retest reliability of the Lactate Pro has been previously reported, with technical error-of-measurement results ranging from 0.1 to 0.4 mmol · L⁻¹ at blood lactate concentrations of 1 to 18 mmol · L⁻¹. Blood lactate was measured immediately preexercise, after the 15-minute fixed-workload part of EX, and at the end of EX. During EX, heart rate was recorded using a RS800 heart-rate monitor (Polar Electro Oy, Kempele, Finland) set at a sample frequency of 1 Hz. The average heart rate over the first 15-minute fixed-workload section of EX was used for analysis.

Subjects were also required to give ratings of their perceived leg-muscle soreness on a scale of 1 (no soreness) to 10 (very, very sore). Ratings were given while subjects contracted their leg muscles in the half-squat position and were taken immediately pre-EX and post-EX.

A nonstretch anthropometric measuring tape (Lufkin, USA) was used to measure the circumference of the upper leg and lower leg pre-EX and post-EX. 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. On the lower leg, the landmark used was at the widest girth of the calf muscle. Measurement sites were marked with a permanent marker to ensure retest reliability (pre-EX and post-EX). Circumference measurements were taken as an indicator of acute changes in limb volume, likely to occur from osmotic fluid shifts or inflammation, which has often been associated with muscle damage.

Statistical Analyses

Data are reported as mean ± SD unless otherwise stated. Magnitude-based inferences were used to identify practically significant differences between trials for each physiological and performance response during EX via analysis of log-transformed values, to reduce the bias arising from nonuniformity of error. Ratings of perceived exertion and perceived soreness were analyzed without log-transformation. The likelihood of the true effects being practically positive, trivial, or negative were calculated by dividing the changes by the appropriate between-subjects standard deviation or by using a known value for the smallest worthwhile change (eg. 1% for mean power). Thresholds for assigning qualitative terms to likelihoods were as follows: <1%, almost certainly not; <5%, very unlikely; <25%, unlikely or probably not; <50%, possibly not; >50%, possibly; >75%, likely or probable; >95%, very likely; and >99% almost certain. Effect sizes (ES) were also calculated using Cohen d, with an ES of .2 being considered the smallest worthwhile positive effect.

The effect was deemed unclear if its confidence interval overlapped the thresholds for small positive and negative effects. To make inferences about the likely range of the true effect, the uncertainty in the effect was expressed as 95% confidence limits. Statistical significance was set at P < .05 for all analyses.

Results

There was a significant difference (P = .02) in performance as evidenced by the higher mean power output in the compression-garment (COMP) trial compared with the CON trial (313.5 ± 29.7 and 309.3 ± 25.3, respectively—Table 1). Although this difference was only associated with a trivial ES, .14, the performance benefit was associated with a 71% practical likelihood of COMP producing a positive effect compared with CON, indicating a possible benefit (Table 1). Figure 1 highlights that 10 of the 12 subjects in the current study had a higher mean power output in the COMP trial than in the CON, with a difference of 1.3% in favor of the COMP trial. Even though 10 of 12 subjects produced a higher mean power in COMP, only 6 of these subjects achieved a mean power output greater than the considered smallest worthwhile change for the test (>1%). The possible trend toward performance benefits was supported by a significantly lower heart rate during the fixed-work-rate section of the test in COMP compared with CON (ES = –.38, very likely beneficial), and also by a trend toward reduced swelling/pooling as evidenced by lower calf-girth measurements preexercise to postexercise in the COMP trial (ES = –.19, possibly beneficial). There were no significant differences between trials for thigh girth, blood lactate, or perceived muscle soreness at any time during the study, all resulting in either unclear or trivial effects.
Table 1  Values for the Measured Variables in the COMP and CON Trials

<table>
<thead>
<tr>
<th>Variables measured during the fixed work-load component of the test</th>
<th>COMP, Mean ± SD</th>
<th>CON, Mean ± SD</th>
<th>COMP – CON, % ± 95% confidence limits, effect size</th>
<th>P</th>
<th>Likelihood of COMP being positive; qualitative outcome (compared with CON)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean power (W)</td>
<td>313.5 ± 29.7</td>
<td>309.3 ± 25.3</td>
<td>1.3 ± 1.0, ES = 0.14</td>
<td>.02*</td>
<td>71%; possibly beneficial</td>
</tr>
<tr>
<td>Δ perceived soreness (pre-EX to post-EX)</td>
<td>5.7 ± 2.0</td>
<td>6.3 ± 2.1</td>
<td>–0.5 ± 1.3, ES = –0.22</td>
<td>.47</td>
<td>56%; unclear</td>
</tr>
<tr>
<td>Δ calf girth (cm, pre-EX to post-EX)</td>
<td>–0.2 ± 0.4</td>
<td>0.2 ± 0.3</td>
<td>–1.0 ± 0.7, ES = –0.19</td>
<td>.007*</td>
<td>50%; possibly beneficial</td>
</tr>
<tr>
<td>Δ thigh girth (cm, pre-EX to post-EX)</td>
<td>0.4 ± 0.6</td>
<td>0.8 ± 0.7</td>
<td>–0.7 ± 1.2, ES = –0.10</td>
<td>.22</td>
<td>15%; unlikely beneficial</td>
</tr>
<tr>
<td>Variables measured during the fixed work-load component of the test</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>mean heart rate^a (beats/min)</td>
<td>159.0 ± 10.7</td>
<td>163.1 ± 9.6</td>
<td>–2.6 ± 2.3, ES = –0.38</td>
<td>.03*</td>
<td>89%; very likely beneficial</td>
</tr>
<tr>
<td>Δ blood lactate^b (pre-EX to 15-min EX)</td>
<td>5.9 ± 2.3</td>
<td>6.4 ± 2.2</td>
<td>–8.8 ± 31.5, ES = –0.20</td>
<td>.47</td>
<td>56%; unclear</td>
</tr>
</tbody>
</table>

Abbreviations: COMP indicates compression garments; CON, control; EX, exercise.

^a Mean heart rate recorded during the 15-min fixed-workload component of the test. ^b Change in blood lactate concentration (mmol · L⁻¹) from pretest to the end of the 15-min fixed-workload component of the test.

*Significant difference (P < .05).
Discussion

The findings in the current study suggest that relative to a control garment (above-knee cycling shorts), wearing lower body compression garments during a 30-minute cycling performance test resulted in a significantly higher mean power output ($P < .05$) and a possible benefit (71% likelihood of a positive effect) to exercise performance when using magnitude-based-inference analysis. However, this suggested improvement in power output was only associated with a trivial ES, .14, which was less than the generally accepted smallest worthwhile effect size of .2. This would suggest that while the effect is unlikely to be large, there does seem to be some benefit in wearing compression garments during exercise.

The results of the current study do not support those described in Scanlan et al\textsuperscript{21} and Burden and Glastier,\textsuperscript{22} who did not report any performance improvements in cycling performance over longer durations (40–60 min) in moderately to well-trained athletes. However, while Scanlan et al\textsuperscript{21} did not find any benefits to 1-hour time-trial performance, they did find possible benefits to muscle oxygenation economy and power output at the anaerobic threshold. The findings in the current study are of a similar magnitude to the results observed in previous studies on the use of compression garments during endurance running.\textsuperscript{9,10} Goh et al\textsuperscript{9} reported a trivial (.15) and small (.48) ES when subjects wore lower body compression garments during a time-to-exhaustion run in cold (10°C) and hot (32°C) environments, respectively, in 10 recreational runners. Similarly, Kemmler et al\textsuperscript{10} reported a small effect (.40) on running performance in 21 moderately trained athletes wearing compression stockings. However, the current study adds to previous literature by supporting the use of compression garments during endurance exercise in a more highly trained population.

Mechanisms associated with improved performance during exercise when wearing compression garments remain largely unclear.\textsuperscript{2} The pressure gradient applied by compression garments has been suggested to improve both venous blood flow and venous return.\textsuperscript{30} Heart rate was used as a surrogate measure of venous return in the current study (based on the assumption that increased venous return will improve end-diastolic volume and stroke volume, thus eliciting a reduced heart-rate response to maintain similar cardiac output). Although this is a crude method of assessing venous return, we found a significantly lower heart rate in COMP than in CON (mean ± 95% CI –2.6% ± 2.3%) during the fixed-workload section of the exercise test. The lower mean heart rate was associated with a 89% practical likelihood of a positive effect in the COMP trial. While it seems intuitive that compression garments will result in a lower heart rate at the same given work intensity due to their blood-flow-enhancing properties, very few studies have reported this,\textsuperscript{14} and many have not found any difference in heart rate when wearing compression garments.\textsuperscript{18,19,21} Indeed, it may be that previous studies did not use levels of compression adequate to promote blood flow; however, the literature is difficult to interpret in relation to the pressure

![Figure 1](image-url)  

**Figure 1** — Percentage difference in mean power for individual subjects in the lower-body-compression-garment (COMP) trial relative to the control (CON) trial. Dashed line represents the smallest beneficial or harmful change in performance (± 1%).
applied, because, like the current study, very few studies have accessed the technology to measure these levels of compression.\textsuperscript{2} Dascombe et al\textsuperscript{14} described differences in regional blood flow when wearing recommended-size and undersized compression garments, suggesting that the level of pressure the garment exerts may be an important aspect in compression research. Optimal levels of pressure may cause increases in venous flow, stroke volume, and, subsequently, improved \(O_2\) delivery during exercise.\textsuperscript{11} Scanlan et al\textsuperscript{21} also supported this hypothesis by showing that muscle oxygenation was increased in the active tissue during endurance cycling. It is possible that improved \(O_2\) delivery via increases in blood flow can be partly attributed to the improvements in performance highlighted in the current study when wearing compression garments.

Similar to a previous study on cyclists, there were no differences in levels of perceived muscle soreness or blood lactate concentration between the COMP and CON groups during the exercise task.\textsuperscript{21} Given that endurance cycling is low-impact, primarily concentric with minimal levels of muscle oscillation, we would not expect to see large differences in muscle soreness similar to those seen in running studies. However, 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 fibers, attenuating the inflammatory response and reducing muscle soreness.\textsuperscript{4,5} The current study would support this theory regarding the reduction in swelling and inflammation as identified by the possibly beneficial reduction in calf-girth measurements after the exercise period in the COMP compared with CON (Table 1); however, this did not appear to reduce the perception of muscle soreness in the COMP trial.

Placebo effects are difficult to control for in compression-garment research, and when any performance effects are found, it is often difficult to delineate them.\textsuperscript{2} 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 the fact that they were all familiar with wearing compression garments on a regular basis. It is possible that the placebo effect contributed to the small performance benefit in the current study. However, the supporting physiological data (eg, lower heart rate at a fixed intensity) would suggest there may be other benefits to wearing compression garments during exercise that are not accounted for by the placebo effect alone. A further limitation of the current study was that the level of pressure the compression garments exerted on the lower limbs of each individual subject was not measured. Conversely, the optimal levels of compression for increasing blood flow in athletic populations are relatively unknown. While there is a plethora of research in the medical setting investigating differing levels of compression for improving blood flow in patients with various venous insufficiencies, the optimal level of compression in a sporting context is yet to be evaluated, suggesting a future area of important research.

### Practical Applications

Wearing lower body compression garments during cycling events lasting ~30 minutes may lead to improvements of ~1.3\% in highly trained cyclists. Even improvements of this magnitude may influence competition success. This may be applicable to certain track cycling events (eg, scratch race, points race) or even cycling time trials over distances of 15 to 20 km. Further research is required to determine whether these results can be applied to athletes from other sports looking to improve performance during endurance-exercise events of similar durations.

### Conclusion

The current study has shown that wearing lower body compression garments during endurance cycling may assist in performance, perhaps through enhanced blood flow and/or redistribution of blood flow as evidenced by a lower mean heart rate during fixed-intensity exercise. However, given that the difference in performance was slightly lower than the smallest worthwhile ES, coupled with the potential for a placebo effect, the actual performance improvement when wearing compression garments is likely to be trivial, suggesting that future research in highly trained cyclists is warranted. Furthermore, because the placebo effect may contribute to the performance improvements, mechanistic trials are needed to determine the physiological changes when wearing the garments (eg, altered blood flow, oxygen economy and delivery to the exercising muscles, reduced muscle oscillation, and thermoregulation).

### Acknowledgments

While the manufacturers of the compression garments (2XU) have a partnership with the Australian Institute of Sport (AIS), the study was performed independently with no input from 2XU into the design, data collection, analysis, or reporting of the results presented in this article. In addition, the AIS is permitted to publish any research findings regardless of the outcome. The funding for this project was provided by the AIS.

### References


