RUNNING PERFORMANCE WHILE WEARING A HEAT DISSIPATING COMPRESSION GARMENT IN MALE RECREATIONAL RUNNERS

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AU2 [1]*Department of Health Sciences, Public University of Navarre, Spain;* [2]*Department of Physical Education and Sport, University of the Basque Country UPV/EHU, Vitoria-Gasteiz, Spain; and* [3]*Department of Sport Science, University of Stellenbosch, South Africa*

ABSTRACT

Leoz-Abaurrea, I, Santos-Concejero, J, Grobler, L, Engelbrecht, L, and Aguado-Jiménez, R. Running performance while wearing a heat dissipating compression garment in male recreational runners. *J Strength Cond Res* XX(X): 000–000, 2016—The aim of this study was to investigate the effects of a *heat dissipating* compression garment (CG) during a running performance test. Ten male recreational runners (mean ± *SD*: age 23 ± 3 years; $\dot{V}O_2max$ 55.8 ± 4.8 ml·kg^{-1}·min^{-1}) completed 2 identical sessions wearing either CG or conventional t-shirt (CON). Each trial included a 45-minute run at 60% of the peak treadmill speed (PTS) followed by a time to exhaustion (TTE) run at 80% of the PTS and a 10-minute recovery period. During the tests, thermoregulatory and cardiovascular responses were monitored. Participants wearing the CG displayed an impaired running performance (508 ± 281 vs. 580 ± 314 seconds, $p = 0.046$; effect size [ES] = 0.24). In addition, a higher respiratory exchange ratio (1.06 ± 0.04 vs. 1.02 ± 0.07, $p = 0.01$; ES = 0.70) was observed at TTE when wearing the CG in comparison to CON. Changes in core temperature did not differ between garments after the 45-minute run ($p = 0.96$; ES = 0.03) or TTE (1.97 ± 0.32 vs. 1.98 ± 0.38° C; $p = 0.93$; ES = 0.02) for CG and CON, respectively. During recovery, significantly higher heart rate and blood lactate values were observed when wearing CG ($p \leq 0.05$). These findings suggest that the use of a heat dissipating CG may not improve running performance in male recreational runners during a running performance test to exhaustion.

KEY WORDS upper body, time to exhaustion, exercise, cardiorespiratory strain, core temperature

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INTRODUCTION

Although the benefits of compression garments (CGs), which include increased venous flow velocity (20) and reduced venous pooling (1) in patients with venous disorders, are widely accepted in the field of clinical and therapeutic medicine, their influence on healthy, active athletes during exercise remains unclear. Manufacturers claim that wearing CGs are associated with performance gains, enhanced perception, and improvements in various physiological responses (2) such as increased muscle blood flow and enhanced blood lactate (BLa) removal (12). However, the effectiveness of CGs during exercise has been questioned by the literature, as reported results are often isolated or inconclusive (18). As an example, while some authors observed improved running performance in moderately trained runners wearing compression stockings (14), others observed impaired running performance in trained runners using similar stockings (25). The lack of consistent findings with sporting CGs has been proposed to be due to the large heterogeneity among studies, including the type, intensity, and duration of the exercise, the training status of the participants, and the type of garment worn (body area covered and the applied pressure) (18).

Recent developments in these garments have led to claims of thermoregulatory benefits. The proposed mechanisms behind these CGs are mainly attributed to increased heat dissipation as a result of improved sweating efficiency, thereby enhancing exercise performance (29). With sweat evaporation from the skin surface being the main mechanism to reduce heat storage during exercise, clothing designs that facilitate heat dissipation may lead to lower core temperature (*T*core) increments and therefore delay the appearance of hyperthermia during exercise. A hypothetically lower core temperature (*T*core) while wearing a CG would then improve exercise performance, considering that an elevated *T*core has been proposed to be a critical factor for fatigue during exercise (22). Nevertheless, previous studies investigating the effects of these *heat dissipating* CGs during 1-hour lasting moderate-intensity exercise (50% $\dot{V}O_2$max) did not observe differences in any thermoregulatory (rectal, skin, and mean body temperature) response (15,16). This questions the validity of the possible ergogenic effects of CGs specifically relating to thermoregulation. Unfortunately, exercise performance was not reported in the aforementioned studies as participants exercised at a moderate intensity and did not reach maximal efforts. Thus, based on previous results (15,16) where wearing a heat dissipating CG did not provide any thermoregulatory benefit during moderate-intensity exercise, this study opted for a high-intensity exercise trial to determine any physiological or performance change between garment conditions (CG vs. control garment [CON]).

The use of CGs has also been proposed to help in athletes' recovery after high-intensity exercise, increasing venous return and improving capillary filtration (24). A possible increase in venous return is hypothesized to help in the removal of waste products (9) and therefore enhance the clearance of BLa (5). Lovell et al. (17) hypothesized that the use of CGs in combination with active recovery would increase the function of the "muscle pump" allowing blood to return to the heart and therefore enhance BLa removal and lower the heart rate (HR) after high-intensity exercise. However, previous research studying the effects of CGs during recovery after high-intensity running reported conflicting results regarding BLa levels (26) showing that the efficacy in the clearance of BLa after high-intensity exercise is limited. Furthermore, it seems that the use of CGs may not mitigate the cardiovascular strain during recovery as no differences in any of the following physiological responses have been observed in previous studies: blood pH, oxygen uptake ($\dot{V}O_2$), or HR (15,16).

Hence, the aim of this study was to analyze the physiological responses of *heat dissipating* CGs during a running performance test to exhaustion. A secondary aim was to examine the effects of CGs during recovery after a high-intensity exercise to exhaustion. It was hypothesized that wearing CGs would not enhance exercise performance during a running performance test to exhaustion. Furthermore, it was hypothesized that CGs would not have any physiological benefit during a recovery period.

Methods

Experimental Approach to the Problem

Manufacturers claim that wearing CGs will improve running performance (29). However, there is limited empirical evidence being available within the scientific literature (2,3,14). To the authors' best knowledge, there is currently no study that has investigated the effects of upper-body CGs on running performance. This study aimed to examine the physiological and performance effects of wearing upper-body CGs during a running performance test. Participants completed a 45-minute run at 60% of the peak treadmill speed (PTS), which is a similar moderate intensity observed in previous studies wearing CGs (21,30). Then, a time to exhaustion (TTE) was performed to monitor running performance effects between garments, as it has been done previously (7,28). Finally, participants rested for 10-minute. Based on the finding of previous studies investigating the effects of upper-body CGs (8,15,16,27), it was hypothesized that wearing CGs would not provide any ergogenic effect on running performance.

Subjects

Ten recreational male runners (mean ± *SD*: age 23 ± 3 years; $\dot{V}O_2$max 55.82 ± 4.84 $ml \cdot kg^{-1} \cdot min^{-1}$; body mass 74.4 ± 7.7 kg; height 180.9 ± 5.5 cm) volunteered to participate in this study. All participants were involved in regular physical activity (at least 4–5 $d \cdot wk^{-1}$) and they were tested between September and October. The Ethics Committee of the Public University of Navarre approved this study, which was conducted in accordance with the principles of the Declaration of Helsinki of 2013. Before participation, runners completed a health questionnaire to rule out any injury or medical condition. All participants were informed about all the tests and possible risks involved and provided written consent before testing. In the 24 hours before testing, participants were asked to refrain from heavy exercise and to abstain from alcohol and caffeine ingestion. Participants were also requested to drink 500 ml of water the night before and 2 hours before the tests to ensure they started the tests in a euhydrated state (11). To minimize circadian variations, all tests were performed at the same time of day. The study conforms to the Code of Ethics of the World Medical Association (approved by the ethics advisory board of Swansea University) and required players to provide informed consent before participation. AU3

Procedures

Participants visited the laboratory on 3 occasions separated by at least 1 week. During their first visit, all participants completed a maximal incremental running test at 0% slope on a treadmill (H/P/Cosmos, Nußdorf, Germany), which started at 9 $km \cdot h^{-1}$ with a 5-minute warm-up. The speed was then increased by 1 $km \cdot h^{-1}$ every minute until volitional exhaustion. During the test, breath-by-breath pulmonary variables were recorded using a gas analysis system (COSMED Quark CPET, Rome, Italy) that was calibrated before each session and verified after each test according to the manufacturer's instructions.

Subjects were considered to have attained their maximal ability and to therefore have reached their $\dot{V}O_2$max when 2 of the following criteria were fulfilled (13): (a) a *plateau* in $\dot{V}O_2$, defined as an increase of less than 1.5 $ml \cdot kg^{-1} \cdot min^{-1}$, (b) a respiratory exchange ratio (RER) >1.15, and (c) a HR > 95% of the age-predicted maximum HR (220-age). Peak treadmill speed was defined as the speed of the last completed stage (23).

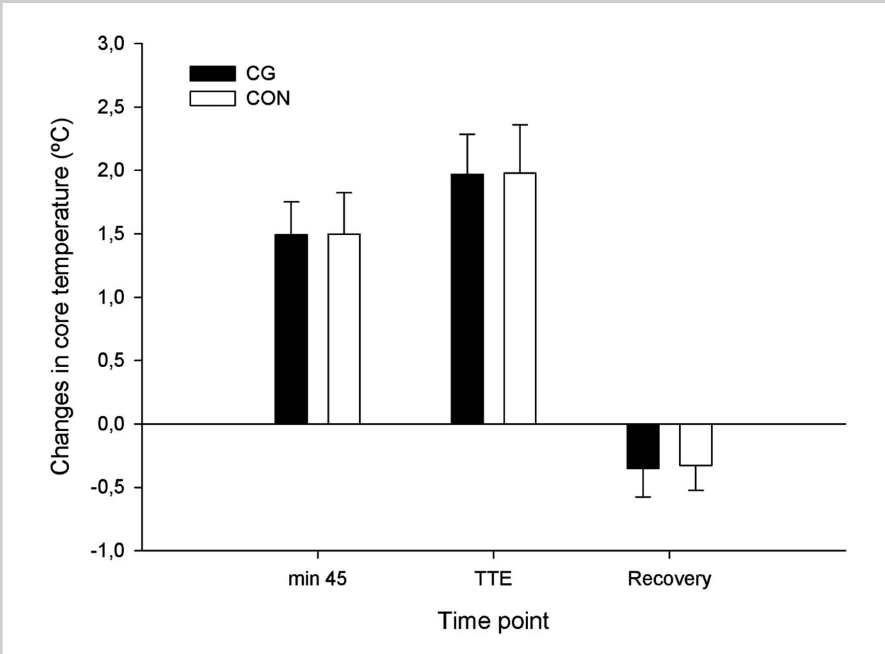

Figure 1. Changes in core temperature (°C) from rest to minute 45 (min 45), from rest to time to exhaustion (TTE), and from TTE to recovery (recovery) wearing compression garments (CG) and control garment (CON).

During visits 2 and 3, participants completed a running performance test wearing either CGs or CON in a randomized order. The test comprised a 45-minute run at 60% of the PTS followed by a TTE run at 80% of the PTS and a 10-minute passive sitting recovery. The tests were performed in an environment at ambient temperature of 20 ± 1° C and with 54 ± 7% relative humidity.

Garment Information. A commercially available (Energy accumulator; X-Bionic, Switzerland) short-sleeve upper-body CGs made of 94% nylon, 4% elastane, and 2% polypropylene was used for the study. The pressure exerted on the upper body was measured using a PicoPress pneumatic pressure sensor (Microlab, Ponte S. Nicolo', Italy) at 4 sites: the *biceps brachii*, *triceps*, *pectoralis major*, and *latissimus dorsi* muscles. Measurements were taken with the participants in the anatomical position. Control garment was 100% cotton, conventional, noncompressive, short-sleeve t-shirt (Domyos, France). Participants used identical shorts and running shoes during testing to minimize differences between the tests. Both garments were sized to the subjects based on the manufacturer's instructions and were donned before testing.

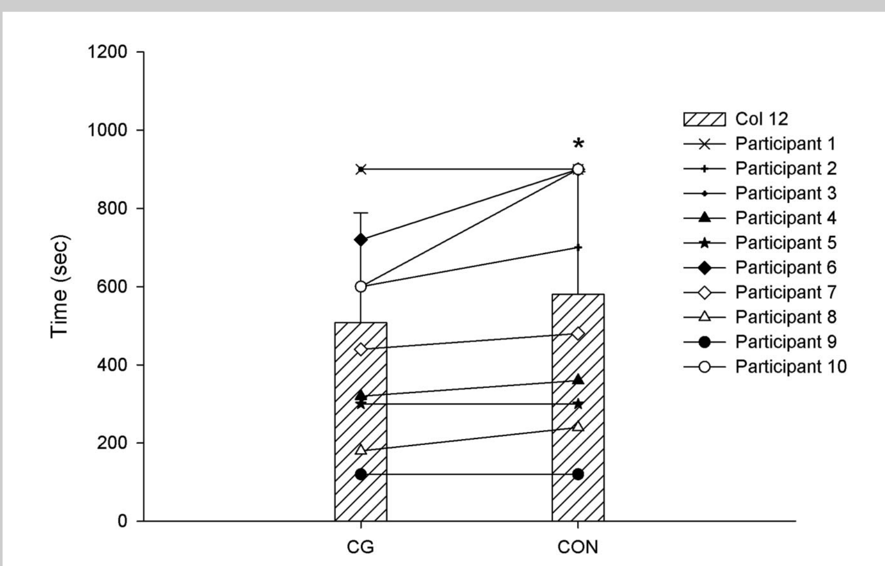

Figure 2. Time to exhaustion of all participants and mean ± *SD* wearing compression garment (CGs) and control garment (CON). $^{*}p \leq 0.05$.

Body Mass Measurements. Nude body mass was recorded immediately before and after the running performance test using a high-precision balance (Seca 899, Hamburg, Germany; accuracy ±0.05 kg).

Core Temperature. Participants' core temperature (*T*core) was continuously measured using a factory calibrated CorTemp Ingestible Temperature sensor (CorTemp; HQ, Inc., FL, USA) that was ingested by the participants 6 hours before the running performance test.

Gas Exchange and Heart Rate. Oxygen uptake ($\dot{V}O_2$), carbon dioxide production ($\dot{V}CO_2$), RER, minute ventilation, and HR were continuously

TABLE 1. Physiological and perceptual responses during the running performance test and recovery.*

Measure	Time point		
	Min 45	TTE	Recovery
HR (b·min^{-1})			
CGs	173 ± 9	191 ± 4	116 ± 9†
CON	169 ± 12	189 ± 5	112 ± 9
$\dot{V}O_2$ (L·min^{-1})			
CGs	2.99 ± 0.41	3.52 ± 0.59	0.61 ± 0.09
CON	2.96 ± 0.38	3.62 ± 0.47	0.62 ± 0.11
$\dot{V}CO_2$ (L·min^{-1})			
CGs	2.73 ± 0.41	3.73 ± 0.67	0.49 ± 0.11
CON	2.66 ± 0.40	3.68 ± 0.53	0.50 ± 0.13
$\dot{V}E$ (L·min^{-1})			
CGs	90.87 ± 15.93	139.08 ± 22.89	20.91 ± 5.57
CON	91.01 ± 18.34	136.43 ± 19.65	20.50 ± 5.82
RER			
CGs	0.91 ± 0.04	1.06 ± 0.04†	0.79 ± 0.07
CON	0.90 ± 0.06	1.02 ± 0.07	0.80 ± 0.08
BLa (mmol·L^{-1})			
CG	3.46 ± 1.13	9.10 ± 1.77	6.80 ± 1.90†
CON	2.84 ± 1.19	7.78 ± 2.14	5.50 ± 1.43
RPE			
CG	14.2 ± 1.1	19.2 ± 0.6	
CON	14.3 ± 1.9	19.2 ± 0.8	

*TTE = time to exhaustion; HR = heart rate; CGs = compression garment; CON = control garment; $\dot{V}O_2$ = oxygen uptake; $\dot{V}CO_2$ = carbon dioxide production; $\dot{V}E$ = ventilation; RER = respiratory exchange ratio; BLa = blood lactate; RPE = rating of perceived exertion.
†$p \leq 0.05$.

monitored throughout rest, exercise, and recovery using a breath-by-breath gas analyzer system (COSMED Quark CPET, Rome, Italy). Volume calibration was performed at different flow rates with a 3-L calibration syringe (COSMED, Rome, Italy), and calibration of the gas analyzer was automatically performed by the system using a known gas mixture (16% O_2 and 5% CO_2).

Blood Lactate and Rating of Perceived Exertion. Capillary blood samples were obtained from the right index fingertip to measure BLa concentration using a portable lactate analyzer (Lactate Pro, Arkray, KDK Corporation, Kyoto, Japan) at 45-minute, at TTE, and after 10 minutes of recovery. *Blood lactate clearance* was defined as the amount of BLa reduced from TTE until 10 minutes of recovery. Each participant's rating of perceived exertion (RPE) was recorded using a 6–20 Borg scale (4) at min 45 and TTE.

Statistical Analyses

A two-way repeated measures (garment condition × time) analysis of variance (ANOVA, SPSS version 17.0) AU5 was used to identify significant differences between the conditions (CGs and CON) in the physiological variables. If a main effect was detected, post hoc analysis was conducted with Tukey's honestly significant difference test to assess individual differences. A paired Student's *t* test was used to compare weight loss and TTE of both conditions. The magnitudes of the differences or the effect sizes (ES) were calculated according to Cohen's *d* (6) and were interpreted as trivial (<0.2, trivial), small (0.2–0.49), moderate (0.5–0.79) and large (≥0.8). Statistical significance was set at $p \leq 0.05$. Data are presented as the mean ± *SD*.

RESULTS

No differences in weight loss were found between garment conditions after the running performance test (1.38 ± 0.30 vs. 1.45 ± 0.32% for CGs and CON, respectively; $p = 0.36$; ES = 0.22, small effect). The pressure applied by the CGs was 2.9 ± 1.5 mm Hg at the *biceps brachii*, 3.0 ± 1.0 mm Hg at the *triceps*, 2.0 ± 0.5 mm Hg at the *pectoralis major*, and 1.4 ± 0.5 mm Hg at the *latissimus dorsi*.

Changes in *T*core did not differ between garment conditions at min 45 (1.49 ± 0.26 vs. 1.50 ± 0.32° C; $p = 0.96$; ES = 0.03, trivial effect), TTE (1.97 ± 0.32 vs. 1.98 ± 0.38° C; $p = 0.93$; ES = 0.02, trivial effect), or recovery (−0.35 ± 0.23 vs. −0.33 ± 0.20° C; $p = 0.82$; ES = 0.09, trivial effect) for CGs and CON, respectively (Figure 1). However, TTE was significantly shorter in the CGs condition compared with CON (508 ± 281 vs. 580 ± 314 seconds, respectively; $p = 0.046$; ES = 0.24, small effect) (Figure 2). The TTE was shorter in the CGs condition for 6 participants, resulting in a 19% decrease. Paired sample *t* test showed no significant difference ($P = 0.42$; ES = 0.10, trivial effect) for order effect between the first (528 ± 276 seconds) and the second (560 ± 322 seconds) running performance test. Furthermore, a significantly higher ($p = 0.01$; ES = 0.70, moderate effect) RER was observed at TTE wearing CGs (1.06 ± 0.04) compared with CON (1.02 ± 0.07) (Table 1).

During recovery, significantly higher HRs were observed in the CGs condition (116.4 ± 8.9 b·min^{-1}) compared with CON (111.8 ± 9.4 b·min^{-1}; $p = 0.04$; ES = 0.50, moderate effect). Furthermore, BLa was significantly higher ($p = 0.017$; ES = 0.77, moderate effect) in the CGs condition during recovery. After the 10-minute recovery, BLa clearance was similar in both conditions (2.45 ± 1.06 vs. 2.24 ± 2.08 $mmol \cdot l^{-1}$ for CGs and CON, respectively; $p = 0.78$; ES = 0.12, trivial effect). No differences between conditions were found for $\dot{V}O_2$, $\dot{V}CO_2$, $\dot{V}E$, and RPE during the test (Table 1).

Discussion

The major finding of this study was that the use of upper-body CGs did not provide any ergogenic effect on performance and recovery. Time to exhaustion was significantly shorter when wearing CGs in comparison to CON during the running performance test (Figure 2). Present findings are in agreement with a previous study that examined the effects of CGs on cross-country runners during a maximal treadmill test (25). In that study, the decrements in the maximal running test until exhaustion were mainly attributed to psychological effects (possible negative perceptions of CGs) because of a lack of differences in physiological responses. However, the only perceptual data recorded (RPE) did not differ between garments (CGs vs. non-CGs) at time to fatigue, which makes it difficult to state that the discomfort created by the CGs was the principal reason for a reduced time to fatigue. It is important to note that participants were not familiarized to wearing CGs which could have increased athletes' discomfort. Rider et al. (25) suggested that this possible discomfort may have negatively affected performance. However, a recent study (3) showed no significant differences in running performance during a marathon run despite the familiarization of the athletes to CGs. Therefore, it cannot be stated with certainty that the perceptual responses to CGs were responsible for an impaired running performance, indicating the need for further research.

Significantly higher RER values were observed wearing CGs compared with CON at TTE (Table 1). Present findings are in agreement with a previous study that reported higher RER values when wearing CGs during high-intensity running (85% $\dot{V}O_2max$) (17). However, the authors suggested that the higher RER values were due to a greater release of CO_2 from the buffering of lactate. In this study, lactate values at TTE were 9.10 ± 1.77 $mmol \cdot l^{-1}$ for CGs and 7.78 ± 2.14 $mmol \cdot l^{-1}$ for CON, which indicates that a significantly higher RER wearing CGs did not lower BLa levels in comparison to CON. Since BLa concentration is the most important determinant of RER during high-intensity exercise (10), higher lactate values may have caused significantly greater RER. Furthermore, it is possible that the use of the CGs may a have greater metabolic cost because of the pressure exerted on the muscles of the respiratory system, as it has been proposed before (15). However, the lack of differences in BLa levels and cardiorespiratory responses at exhaustion leads us to interpret these results with caution.

The pressure exerted by CGs was similar to that reported (~5–7 mm Hg) in other studies (8) and was considered as light compression. In that study, Dascombe et al. (8) studied the effects of upper-body CGs in elite kayakers during short, high-intensity protocol (6 × 6-minute step kayaking followed by 4-minute performance test) and concluded that CGs did not provide any physiological or performance benefit. Despite similar pressures applied, the type of exercise (kayak vs. running), intensity and duration of the exercise, and the training status of the participants (elite vs. recreational) resulted in completely different outcomes in comparison to this study, which makes the comparison of results more difficult. Nevertheless, these results are in agreement with previous studies (8,27) demonstrating that wearing of upper-body CGs did not provide any ergogenic effect on performance.

The CGs did not mitigate the cardiovascular strain during recovery. Heart rate and BLa levels remained significantly higher in the CGs after 10-minute of passive sitting (Table 1). The present results go against manufacturers' claims of the possible benefits of wearing CGs during the recovery period. A suggested benefit includes improved capillary filtration that would help in the removal of the metabolic by-products and facilitate a faster return of blood gas homeostasis (17). Nevertheless, the use of CGs did not help in the removal of BLa levels better than CON. Furthermore, recently Leoz-Abaurrea et al. (15) observed smaller reductions in HR when wearing CGs during recovery and suggested that the use of this CGs may increase the cardiorespiratory strain. In view of the above, present results suggest that the use of CGs would not help to mitigate the cardiovascular strain during passive recovery after a maximal running performance test.

As stated by manufacturers, the use of CGs would facilitate heat dissipation and therefore enhance exercise performance. The results reported in this research suggest that the use of CGs did not benefit the thermoregulatory responses (changes in *T*core) during exercise. This apparent lack of CGs effect on thermoregulatory responses, as indicated by changes in *T*core, is in agreement with previous research (15,16), and it probably indicates that this type of garment is ineffective (in terms of thermoregulation at least) during moderate or high-intensity exercise. Furthermore, a previous study (19) has shown that CGs do not benefit either thermoregulatory function or exercise performance during 1-hour fixed load cycling (65% $\dot{V}O_2max$) and 6-km time trial. Hence, we may conclude that the use of CGs in this study was not effective to reduce changes in *T*core or to enhance running performance.

Future research should focus on investigating the effects of CGs using typical long distance race protocols (e.g., time trials), where athletes could adapt their race pace instead of having fixed-exercise intensities to simulate real competition. Further research should also examine whether wearing the CGs immediately after the running performance test will cause the same increases in BLa and HR during short-term passive recovery as it did in this study.

Practical Applications

The practical applications of this study seem to demonstrate the inefficacy of *heat dissipating* CGs to improve exercise performance during a running performance test to exhaustion. The use of CGs did not provide any physiological benefit during exercise in male recreational runners. Furthermore, significantly higher BLa and HR were reported during passive recovery. Thus, based on these results, it cannot be stated that the use of these garments serves as an ergogenic aid during either a running performance test to exhaustion or short-term passive recovery. Therefore, runners should be aware of these results during competition and after recovery when wearing CGs in the future.

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