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Original Article (short paper)

Effects of ceramic garments on 10-km running performance

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Abstract — Aims: The use of electromagnetic waves by phototherapy to skeletal muscle presents potential ergogenic effects. The aim of this study was to analyze the effect of using bioceramic clothes on performance, heart rate (HR) and rate of perceived exertion (RPE) during a 10 km race. Our hypothesis is that the use of such clothes modifies these variables. **Methods:** Participants were 10 runners (27.9 ± 4.2 years) who performed two 10 km performances on track under different intervention conditions: bioceramic garments (CER) and placebo garments (PLA). The mean velocity (MV), HR and rate of perceived exertion (RPE) were monitored at each trial. Additionally, partial MV was calculated in three phases: (1) start (first 400 m), (2) middle (400-9600 m) and (3) end (last 400 m). **Results:** MV in CER condition was significantly higher than in PLA condition (11.8 ± 1.0 $km \cdot h^{-1}$ vs 11.4 ± 1.2 $km \cdot h^{-1}$; F = 6.200; P = 0.034; η_p^2 = 0.408). HR and RPE values in CER condition were not different from PLA condition. **Conclusions:** Our main finding was that the use of bioceramic clothes (CER) increased MV when compared to the PLA condition. Based on these results, bioceramic may be used as an ergogenic resource to increase performance.

Keywords: physical endurance, far-infrared radiation, phototherapy, sports

Introduction

Participation in street races has increased in the last few years, especially for ten kilometers runs[1]. In parallel to this, there has been an increase in ergogenic resources, defined as any mechanism with physiological, nutritional or pharmacological action that is capable of modifying performance[2].

The use of electromagnetic waves by application of light- or radiation-emitting devices (*i.e*., phototherapy) to skeletal muscle presents potential ergogenic effects, improving contractile function, performance and other aspects related to exercise recovery[3,4].

There are many different ways to apply the phototherapy, such as lasers, light-emitting diodes (LED) and, more recently, garments made up of fibers impregnated with far-infrared emitting nanoparticles (bioceramic)[3,4]. These clothes work as black bodies or perfect absorbers, absorbing and reflecting the infrared energy emitted from the human body[4].

Recent research indicates that bioceramic may produce beneficial effects, such as lowering resting energy expenditure and heart rate (HR), pain relief in patients with inflammatory joint disease, decrease in muscular pain sensation and increased performance in anaerobic tests[5-7].

Although there are studies in humans using bioceramic clothes[5,8], there has not been studies analyzing the potential effects of bioceramic clothes on 10 km running performance . These results may provide evidences regarding the acute effect of using this strategy for endurance runners. Therefore, the aim of this study was to analyze the effect of using bioceramic clothes on performance, heart rate (HR) and rate of perceived exertion (RPE) during a 10 km race. Our hypothesis is that the use of such clothes modifies these variables.

Materials and Methods

Subjects

Ten healthy young males volunteered to participate in this study. All participants gave their informed consent for participation in the research study, were physically active with 10 km performance time between 40-60 minutes. The training characteristics were with frequency 3 days per week, weekly training volume of approximately 20 km, and at least one year of experience in running, presented cardiovascular statement to perform exhaustion physical tests, had no recent muscle injury or lower limb bone or joint diseases, and reported no use of medication or nutritional supplementation with ergogenic or anti-inflammatory effect. Characteristics of the participants (mean ± SD) were: age 27.9 ± 4.2 years, height 1.8 ± 0.1 m, body mass 73.0 ± 7.5 kg, body mass index (BMI) 23.5 ± 2.3 $kg \cdot m^2$ and body fat 19.3 ± 4.2%. Prior to testing, written informed consent was obtained from all participants. The experimental protocol was approved by the local

Human Research Ethics Board (#681298/2014) and appropriate standards for human experimentation have been followed.

Experimental overview

After familiarization with the protocol, participants visited the track for two 10 km performances under different intervention conditions: bioceramic garments (CER) and placebo garments (PLA). Test order was randomly determined and subjects were blind to the intervention condition. Interval between visits was between 3-7 days. In each visit, participants wore the assigned clothes for an hour before starting the performance test.

Participants were instructed to report for testing well-rested, well-nourished, and well-hydrated, wearing lightweight comfortable clothing. Participants were also instructed to avoid eating 2 h before the maximal exercise tests, to abstain from caffeine and alcohol, and to refrain from strenuous exercise for 24 h before testing[9].

10 km running test

Performances were undertaken on a 400 m outdoor track preceded by a 10 min warm up. Heart rate (HR) was measured continuously throughout the test (Polar, RS800cx, Kempele, Finland), and registered every 400 m. Rate of perceived exertion (RPE) was measured through the 6-20 Borg Scale[10]. The tests were performed at the same time of the day (between 5 and 8 p.m.)[11], under temperatures ranging from 22.2 ± 6.8 °C, with humidity ranging from 54.3 ± 13.4%.

Participants were requested to run as fast as possible and the time was recorded every 400 m. Mineral water was provided *ad libitum* in cups throughout trials, so that runners could hydrate themselves as they were used to do in long-distance races. The overall mean velocity (MV) for each trial was calculated by dividing the total distance covered by the trial duration. Additionally, partial MVs were calculated in three phases: (1) start (first 400 m), (2) middle (400-9600 m) and (3) end (last 400 m), as previously reported[11,12]. These phases were chosen due to the findings of Bertuzzi et al.[11], who identified these distances are determined by different factors (*e.g.*, start: Rate of perceived exertion; middle: VO_{2max}, peak running aerobic speed, and 1 repetition maximal for lower limbs; end: peak running aerobic speed).

Bioceramic garments

In the CER condition, participants wore a short sleeve t-shirt (100% polyamide), knee-length shorts (88% polyamide, 12% elastane), and stockings up to the knees (66% polyester, 18% elastodiene, 16% cotton), in which bioceramic powder composed of alumina, magnesium oxide, titanium oxide and silica were incorporated to the polymer (information provided by the fabricant – Bios®, São José do Rio Preto, São Paulo - Brazil). Identical items were worn in the PLA condition; however, bioceramic powder was not incorporated to it, thus, no ceramic particles were present[13]. We used Small and Medium sized garments, and they were adjusted individually for each participants.

Statistical Analysis

Data are presented as mean ± standard deviation (SD). Shapiro-Wilk test was used to verify the normal distribution of the outcomes. The comparison of the mean velocity and the total performance time of 10 km between the conditions was made by the Paired *T Test*. Results for MV, HR and RPE recorded at the three different points during performances were compared using two-factor ANOVA for repeated measures followed by the LSD *post hoc* test for multiple comparisons. The assumption of sphericity was verified using the Mauchly test and when violated the degrees of freedom were corrected using Greenhouse-Geisser sphericity estimates. Analyses were conducted with the aid of the Statistical Package for the Social Sciences (SPSS) version 13.0. For all analyses, a significance level of $P < 0.05$ was adopted.

Results

MV in CER condition was significantly higher than in PLA condition (11.7 ± 1.0 $km \cdot h^{-1}$ *vs* 11.3 ± 1.2 $km \cdot h^{-1}$; $P = 0.036$). Total time of performance for the CER condition was significantly lower than in PLA condition (51.0 ± 3.6 min *vs* 53.1 ± *vs* 5.1 min; $P = 0.023$).

There was a main effect of the phase (start, middle and end phase) of the event in MV ($F = 12.194$; $P < 0.001$; $\eta_p^2 = 0.575$), but there no of the condition ($F = 0.001$; $P = 0.979$; $\eta_p^2 < 0.001$), and there was no significant interaction between the phase and the condition ($F = 1.285$; $P = 0.301$; $\eta_p^2 = 0.125$). In PLA condition, MV at the start phase was higher than at the middle phase ($P <$ 0.001) and not different from the end phase ($P = 0.257$). MV at the middle phase was lower than at the end phase ($P = 0.032$) (fig. 1). For CER condition, MV at the start phase was higher than at the middle ($P < 0.001$) and end phases ($P = 0.022$). However, MV at the middle phase did not differ from MV at the end phase (P = 0.144) (fig. 1). In the first phase of the event, MV of the CER condition (13.4 ± 1.4 $km \cdot h^{-1}$) did not differ from PLA (13.4 ± 1.7 $km \cdot h^{-1}$; $P = 0.954$). At the middle phase (400-9600 m), MV was significantly higher in CER *vs* PLA condition (11.7 ± 1.0 $km \cdot h^{-1}$ *vs* 11.3 ± 1.2 $km \cdot h^{-1}$; $P = 0.034$). At the end phase (9600-10000 m), there was no difference between CER and PLA (12.3 ± 1.1 $km \cdot h^{-1}$ *vs* 12.6 ± 1.2 $km \cdot h^{-1}$; $P = 0.322$) (fig. 1).

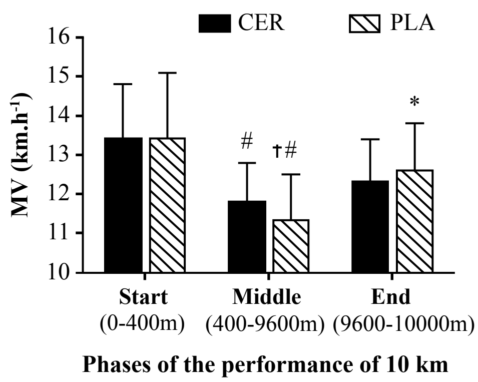

Figure 1. MV during the different phases adopted by the participants of the present study. *P < 0.05 vs the middle phase (400-9600 m) for the same condition; #P < 0.05 vs the start phase (0-400 m) for the same condition; †P < 0.05 comparing the conditions for the middle phase (400-9600 m).

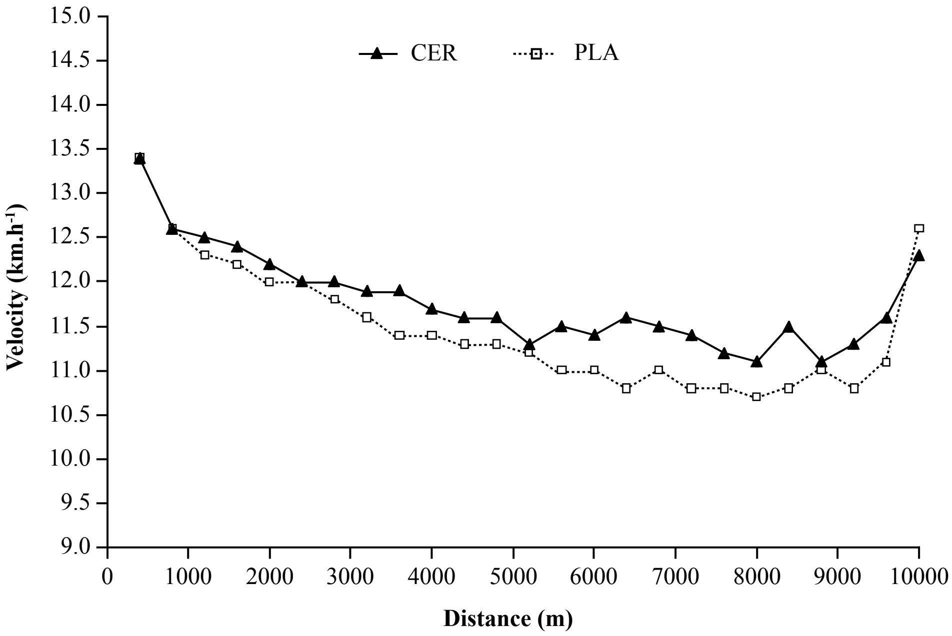

Figure 2. Mean velocity during the performance of 10 km, for PLA condition and CER condition.

There was a main effect of the phase (start, middle and end phase) of the event in HR ($F = 12.241$; $P = 0.005$; $\eta_p^2 = 0.576$), but no condition effect ($F = 0.351$; $P = 0.568$; $\eta_p^2 = 0.037$), and there was no significant interaction between phase and condition ($F = 0.230$; $P = 0.668$; $\eta_p^2 = 0.025$). In PLA condition, HR at the start phase was lower than at the middle ($P = 0.024$) and end phases ($P = 0.005$). HR at the middle phase was lower than in the end phase ($P = 0.002$). For CER condition, HR at the start phase was lower than at the middle ($P = 0.049$) and end phases ($P = 0.010$). HR at the middle phase was lower than at the end phase ($P = 0.001$).

In the first phase of the event, HR at CER (152 ± 29.9 bpm) did not differ from HR at PLA (146 ± 35.2 bpm; $P = 0.603$). The same is true for the middle phase (400-9600 m - CER *vs* PLA 175 ± 9.7 bpm *vs* 173 ± 11.9 bpm; $P = 0.530$). In the end phase (9600-10000 m), there was also no difference between HR at CER and PLA (186 ± 8.4 bpm *vs* 185 ± 8.7 bpm; $P = 0.900$).

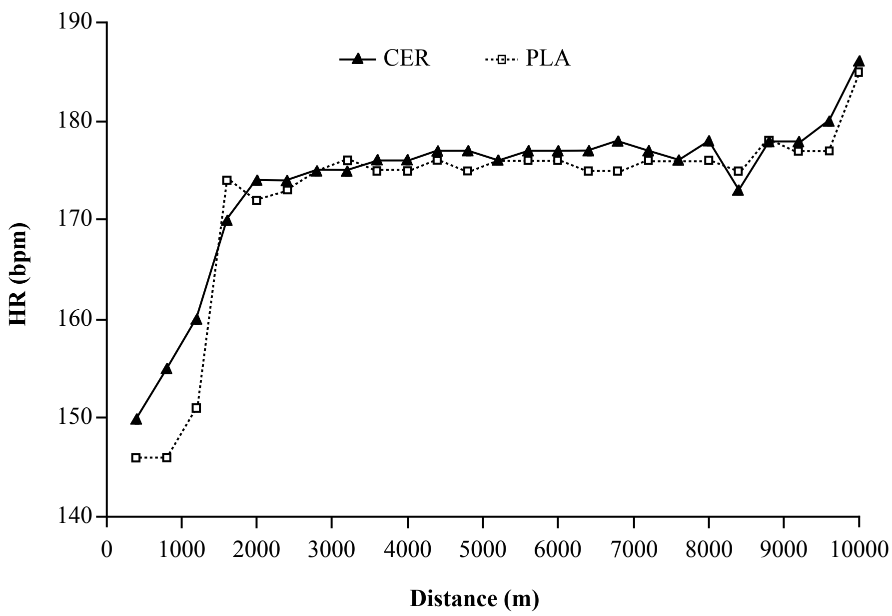

Figure 3. Heart rate (HR) during the performance of 10 km, for condition PLA and CER condition.

There was a main effect of the phase (start, middle and end phase) of the event in RPE ($F = 82.392$; $P < 0.001$; $\eta_p^2 = 0.902$), but no main effect of the condition ($F = 0.585$; $P = 0.464$; $\eta_p^2 = 0.061$), and there was no significant interaction between the phase and the condition ($F = 0.278$; $P = 0.761$; $\eta_p^2 = 0.030$). In PLA condition, RPE at the start phase was lower than at the middle ($P < 0.001$) and end phases ($P < 0.001$). RPE at the middle phase was also lower than at the end phase ($P < 0.001$). For CER condition, RPE at the start phase was lower than at the middle ($P < 0.001$) and end phases ($P < 0.001$). RPE at the middle phase was lower than at the end phase ($P < 0.001$).

In the first phase of the event, RPE at CER (7 ± 1.0) did not differ from PLA (7 ± 1.9; $P = 0.832$) and middle phase (400-9600 m), CER *vs* PLA condition (12 ± 2.9 *vs* 12 ± 2.9; $P = 0.644$). In the end phase (9600-10000 m), there was also no difference between CER and PLA (17 ± 4.1 *vs* 18 ± 2.7; $P = 0.343$).

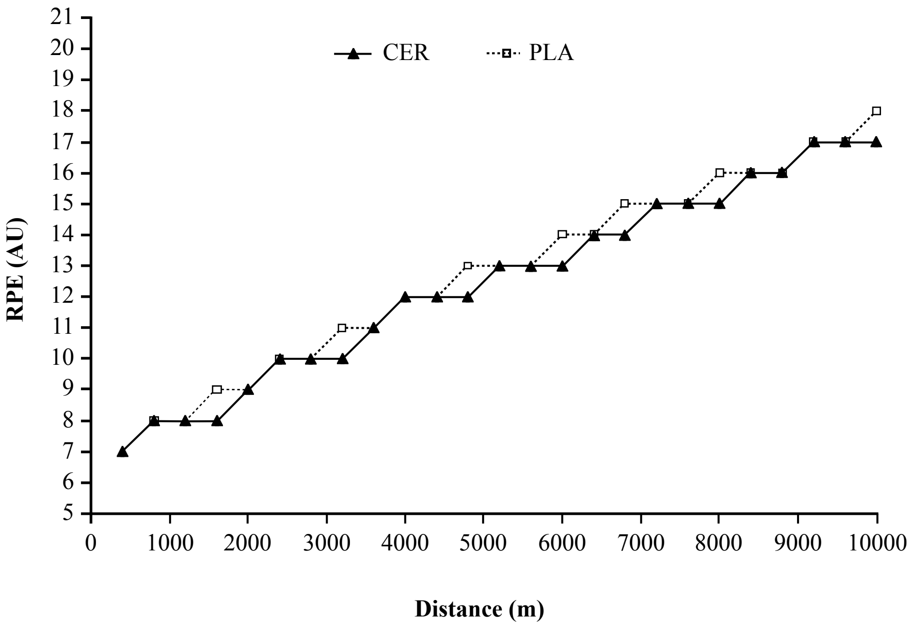

Figure 4. Rate of perceived exertion (RPE) during the performance of 10 km, for condition PLA and CER condition.

Discussion

The aim of this study was to analyze the effect of using bioceramic clothes on performance, heart rate (HR) and rate of perceived exertion (RPE) during a 10 km race. Our main finding was that the use of bioceramic clothes (CER) increased MV during the race and changed the mean velocity when compared to the PLA condition.

Bioceramic materials act as black bodies or perfect absorbers, absorbing and reflecting the infrared energy emitted by the human body[4]. Most of the applications with bioceramic materials are in the medical area, such as for cardiovascular diseases and pain management, given their anti-inflammatory and antioxidant properties[4,14]. To the best of our knowledge, this is the first study that examined the effects of bioceramic clothes on endurance performance (*i.e.*, 10 km race).

One of the main goals of exercise training is to improve performance, and ergogenic resources can contribute to achieve this. The results of the present study suggest that bioceramic clothes are efficient to increase MV to complete a 10 km race. Possible mechanisms related to this change might be related to microcirculation improvement, HR reduction under stress, delayed fatigue status and decreased tiredness, as suggested by previous studies[5,15-17]. Our findings related to HR values during the middle phase of the race corroborate this hypothesis, since similar HR values were observed in the CER compared to the PLA condition despite the intensity being significantly higher for the CER condition. This result might reflect an acute effect on the autonomic nervous system, promoting a better control of sympathovagal balance[5].Few studies have verified the effects of bioceramic clothes in humans, especially during exercise[5,14]. Leung, Kuo, Lee, Kan, Hou[5] assessed non-athletes, and verified the effects of using a bioceramic t-shirt in a treadmill walking testing in a randomized crossover trial. Results showed that when subjects wore the bioceramic t-shirt, there was a tendency towards decreased skin temperature, tiredness and RPE, in addition to greater steadiness of breathing and HR, reflecting increased parasympathetic control.

Studies *in vitro* and in animals have been conducted in an attempt to understand the active principles of bioceramic[15,17,18]. For instance, HR of rats exposed to stressors and isolated hearts of frogs stimulated with adrenaline were lower when bioceramic clothes were dressed[17]. Leung, Lee, Tsai, Chen, Chao[15]electrically stimulated the gastrocnemius muscle of amphibians and demonstrated that bioceramic reduced muscle fatigue and normalized acidification in this tissue, probably due to the antioxidant properties of bioceramic.

Variables such as maximal oxygen uptake (VO_{2max}), running economy (RE), and peak velocity (V_{peak}) are considered good predictors of endurance performance and their application is recommended for exercise prescription and monitoring[9,19-21]. Thus, the improvement of these variables would possibly cause an improved performance. Leung, Lee, Tsai, Chen, Chao[5] measured oxygen uptake and basal metabolic rate of 10 subjects with or without a bioceramic t-shirt and noticed a reduction in these variables when the t-shirt was worn, suggesting a decrease in energy expenditure. Although our study has not determined submaximal oxygen uptake to reflect RE, it could be speculated that changes in this variable would play a role in the improvements in running performance.

Regarding the MV in each phase of the 10 km running performance, in the PLA condition the first and last 400 m were faster than the middle phase. However, the runners performed the start phase faster, and MV decreased throughout the race in the CER condition. There was no significant difference in the first and end phases of the race, when the conditions were compared. However, in the middle phase, MV at the CER condition was 0.4 $km \cdot h^{-1}$ faster than in the PLA.

After assessing the contribution of different muscular and physiological variables to the different phases in the 10 km running performance, Bertuzzi et al.[11] concluded that V_{peak}, VO_{2max} and maximal strength (*e.g.*, 1RM test) explained 80% of the variation in the middle phase of 10 km running performance. As previously discussed, it may be suggested that the increase observed in MV in the middle phase in the CER condition in the present study could be explained by the decrease an increase in aerobic power and RE at this phase[5]. However, it is recommended additional studies to test the acute effect of the bioceramic garments on maximal strength and aerobic power (*i.e.*, V_{peak} or vVO_{2max}) to elucidate the role of these ergogenic clothes on these variables.

In relation to HR changes across each phase of the 10 km race, it increased somewhat steadily up to 1600 m, and then remained stable until the second to last lap, when a new increase was observed in both conditions (fig 3). This progressive increase was also noted in other studies[22,23], and might be directly related to the increase in speed ("sprint") in the last lap (*i.e.*, end phase) (fig 2)[24-26].

The RPE exhibited a similar trend when both conditions were compared, with an increase between phases but no differences between experimental conditions (fig 4). The RPE is related to a process of sensory interaction of the physiological adjustments resulting from the metabolic demand imposed by physical effort[27,28]. Compared to HR and MV, RPE showed a different trend, and increased steadily until the end of the race. Similar results were noticed by Bertuzzi, Nakamura, Rossi, Kiss, Franchini[29], after analyzing the temporal independence of RPE and HR responses in relation to running speed in a 10 km race. The RPE could be modulated by the interaction of cognitive and contextual factors[30]. It is possible that RPE had been modulated by the participants in the present study in order to complete the 10 km distance in the shortest amount of time, based on previous experiences, seeking to finish the performance with maximal RPE values[29].

Even with the differences observed in our study, results should be analyzed with caution, since the sample size is small and a placebo effect might have occurred. Future studies should focus on providing conclusive evidence on bioceramic garments as an ergogenic aid.

Conclusions

Based on the results, bioceramic could be used as an ergogenic resource to increase performance, given the benefits promoted in the middle phase of the race and cost compared with other phototherapy approach.

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