Effect of ceramic-impregnated clothing on a 10 km running performance

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Abstract

This study aimed to analyze the effects of using bioceramic clothing on the 10 km running performance. Ten healthy young males (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·m^2 and body fat 19.3 ± 4.2 %) volunteered to participate in the study. The participants visited the track for three 10 km performances under different conditions: bioceramic clothes (CER), placebo (PLA) and personal clothes (C). Test order was randomized and subjects were blind to the intervention condition, except for the C. Friedman's test or ANOVA for repeated measures were used to compare the conditions. Minimal detectable change and Effect Size were also calculated. *Results:* No statistical differences were found. Minimal detectable change analysis suggested a "Possible" reduction in time for the CER condition (C – 52.3 ± 4.1; PLA – 53.1 ± 5.0; CER 51.4 ± 3.8 minutes). Lactate concentration analysis showed a faster removal when subjects were using bioceramic clothes. DOMS was rated as "Possible" higher in the CER condition, and the Session Rate of Perceived Exertion ($RPE_{Session}$) was also higher in that condition, rated as "Small" through Cohen's Effect Size analysis (C – 425.7 ± 74.8; PLA – 426.6 ± 87.5; CER – 440.1 ± 42.5 A.U.). *Conclusion:* Results suggest that the use of bioceramic clothes might improve running performance. Further studies are necessary to determine ideal dosage such as time of use and factors influencing absorption.

KEYWORDS: Bioceramic; Aerobic exercise; Far-infrared radiation; Lactate; Muscle soreness.

Introduction

Ergogenic aids in sport are defined as any mechanism with physiological, nutritional or pharmacological action that are capable of modifying the performance[1]. The use of electromagnetic waves by application of light or radiation emitting devices (phototherapy) presents potential ergogenic effects on performance and other aspects of recovery. Because of that, the ease of application and its low cost, this technique has attracted the attention of researchers[2].

There are many different application forms of phototherapy, such as lasers, light-emitting diodes (LED) or garments made up of fibers impregnated with far-infrared (FIR) emitting nanoparticles (bioceramic)[3]. Phototherapy occurs through the absorption of light by tissues, and this may influence cellular activity; the magnitude of this influence is dependent on dosage and wavelength[4].

FIR consists of invisible electromagnetic waves, with wavelengths between 5,6-1000 μm[5]. Bioceramic clothes work as black bodies or perfect absorbers, absorbing and reflecting the infrared energy emitted from the human body[6]. The amount of energy radiated and reflected by the bioceramic clothes varies individually, and also with body temperature and possibly other factors[6].

Studies using animal models, cell culture and humans, indicate that the use of bioceramic triggers effects such as microvascular dilation, higher blood flow, elevated regional tissue temperature, decrease in energy expenditure at rest, pain relief in patients with inflammatory joint disease, reduced heart rate under stress, fatigue retardation, decreased sensation of muscle soreness, anti-oxidant effects and increased performance in anaerobic tests[5,7-13]. It is suggested that some of these effects might be due to increased nitric oxide (NO) and calmodulin[13]. Thus, FIR from bioceramic clothes might influence intracellular activity, in a very similar same way other phototherapy methods do, affecting heat transfer in subcutaneous tissues and other physiological processes[5,14], many of which are directly involved in aerobic performance.

Noponen[12] used FIR as a recovery method during a 5-day training period and observed significant changes in average power at the Wingate test. The author suggested the possibility of FIR inducing a decline in acidosis and faster clearance of metabolic end-products, increasing both muscle fiber conduction velocity and anaerobic performance. Few researchers sought to clarify the effects of bioceramic in humans, but no studies have verified the effect of using bioceramic clothing on aerobic performance.

Thus, the aim of this study was to analyze the effect of using bioceramic clothing on the 10 km running performance; specifically, the following variables were analyzed: total time, heart rate (HR), rate of perceived exertion (RPE), muscle soreness (DOMS), and profile of blood lactate removal. We hypothesized that the use of bioceramic clothing would improve running performance by improving microcirculation blood flow, decreasing muscle soreness, rate of perceived exertion and heart rate.

Methods

Participants

Ten healthy young males (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·m^2 and body fat 19.3 ± 4.2%) volunteered to participate in this study. All participants were physically active with 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 effects.

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).

Experimental Design

A familiarization session was carried out, when participants went through an anthropometric evaluation, were introduced to the Borg Scales (0-10 and 6-20)[15], to the DOMS scale, to the track and the protocol. After that, participants visited the track for three 10 km trials under different intervention conditions: bioceramic clothes (CER), placebo clothes (PLA) and control (C). For the PLA condition, clothes similar to CER were provided; for the C, participants used their personal clothes. CER and PLA clothes included a t-shirt, shorts and shin guards. Test order was randomized and subjects were blind to the intervention condition, except for the C. Interval between visits was between 72 hours and 7 days. In each visit, participants wore the assigned clothes for an hour before starting and during the performance.

Methodology

Performances were undertaken on a 400 m outdoor track preceded by a 10-minute warm up. Heart rate (HR) (Polar, RS800cx, Finland) was measured continuously throughout the test, and registered every 400m. Rate of perceived exertion (RPE) through 6-20 Borg Scale[15] and lap time were registered every 400 m.

Participants were instructed to attend for testing well rested, nourished and hydrated, to refrain from strenuous exercise during the study period and to follow their nutritional routine. They were instructed to complete the distance as fast as possible.

Earlobe capillary blood samples (25 µL) were collected into a glass tube at baseline, at the end of each performance and at the third, fifth and seventh minutes after completion, during passive recovery sitting in a comfortable chair. From these samples, $LA_{baseline}$, $LA_{0\,min}$, $LA_{3\,min}$, $LA_{5\,min}$, $LA_{7\,min}$ were subsequently determined by using the automated analyzer (YSI 2300 STAT, Ohio - USA). The LA_{peak} was defined for each subject as the highest value among $LA_{0\,min}$, $LA_{3\,min}$, $LA_{5\,min}$, $LA_{7\,min}$. It was also determined the difference between LA_{peak} and $LA_{baseline}$ ($\Delta_{peak\text{-}baseline}$), LA_{peak} and $LA_{7\,min}$ ($\Delta_{peak\text{-}7\,min}$), and $LA_{7\,min}$

and $LA_{baseline}$ ($\Delta_{7\ min\text{-}baseline}$) to highlight the increase and removal profile of blood lactate.

Each participant was required to record their perception of muscle soreness (DOMS) 30 minutes after completing each 10 km performance using a visual analogue scale, which consisted of a 100 mm line labeled with "no soreness" on the left and "extremely sore" on the right[16,17]. Volunteers rated their soreness by placing a mark on the line that best corresponded to their perception; this was quantified by measuring to the nearest 1 mm from the left end of the line to the mark made by the participant[16,17]. At this time, participants were also instructed to indicate a value in the Borg 0-10 scale, which was multiplied by total performance time to obtain the Session RPE ($RPE_{Session}$)[18] in arbitrary units (A.U.). The sequence of the assessments is shown in FIGURE 1.

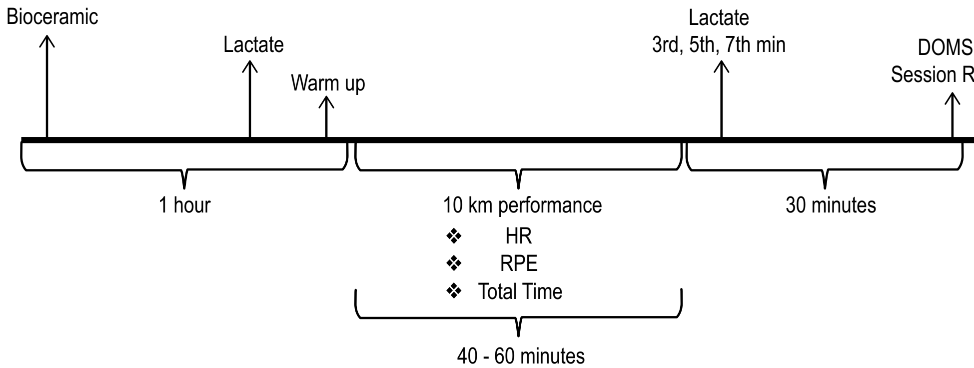

FIGURE 1 – The sequence of the assessments. Flowchat with timeline of the study.

Statistical Analysis

Data are presented as mean ± standard deviation (SD). Shapiro-Wilk test was used to verify the normal distribution of the outcomes.

For non-parametric variables, the comparison was made through Friedman's test. For normal distributed data, comparisons were made using one-way ANOVA for repeated measures followed by the Bonferroni post hoc test. The assumption of sphericity was verified using Mauchly's test and when violated, the degrees of freedom were corrected using Greenhouse-Geisser sphericity estimates. These tests were used for comparing total time, DOMS, HR, $RPE_{Session}$. 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.

Effect size (ES) was used to estimate the magnitude of the difference for total time, DOMS, HR, $RPE_{Session}$. As proposed by Cohen[19], the difference was considered small when $0.2 < ES \leq 0.5$, moderate when $0.5 < ES \leq 0.8$ and great when $ES > 0.8$.

Considering the sample size, we opted to use analysis of practical inferences based on magnitudes[20] to compare the different interventions. The effect was determined qualitatively based on the chance of the effect being beneficial, trivial or harmful (e.g., higher or lower than the minimal important practical effect or minimal detectable change [0.20 times SD of baseline based on effect size])[20]. Therefore, changes were rated as: ≤ 1% almost certainly not; 1-5% very unlikely; 5-25% unlikely; 25-75% possible; 75-95% likely; 95-99% very likely; and ≥ 99% almost certainly. If negative and positive values presented results < 10%, the inference was considered unclear.

Results

TABLE 1 lists the results for variables related to performance in each of the experimental conditions: total time (min), HR (bpm), $RPE_{Session}$ (A.U.) and DOMS (mm). There were no statistical differences between experimental conditions. Data are reported as mean ± standard deviation (SD).

TABLE 2 presents the results from the qualitative analysis, showing a "possible" change for the CER and PLA conditions when compared to the C, CER being the best time and PLA the worst.

FIGURE 2 shows the behavior of HR and RPE through each lap of the 10 km performance in each experimental condition. RPE tended to lower values in CER.

TABLE 3 lists the results from the qualitative analysis of $RPE_{Session}$ (A.U.). The experimental condition that elicited the higher $RPE_{Session}$ was CER, demonstrated by a "possible" change for the CER condition when compared to the C. The ES for this comparison was rated as "small".

TABLE 4 presents the qualitative analysis of DOMS (mm). The minimal detectable change was unclear and ES was rated as "small" for CER when compared with C.

TABLE 5 shows the results from lactate analysis collected at baseline, at the end of each performance and at the third, fifth and seventh minutes after completion and calculations to help analyze the lactate removal after exercise.

TABLE 1 - HR (bpm), $RPE_{Session}$ (A.U.), total time (minutes) and DOMS (mm) obtained in the 10 km performances (n = 10).

Variables	C	PLA	CER	*P*
Total time (min)	52.3 ± 4.1	53.1 ± 5.0	51.4 ± 3.8	0.06
HR (bpm)	182 ± 7.9	183 ± 9.9	184 ± 11.1	0.80
$RPE_{Session}$ (A.U.)	425.7 ± 74.8	426.6 ± 87.5	440.1 ± 42.5	0.80
DOMS (mm)	24.4± 38.1	29.9 ± 34.3	43.0 ± 40.8	0.73

$P < 0.05$
HR = heart rate;
$RPE_{Session}$ = rated perceived exertion of the session;
C = control condition;
PLA = placebo condition;
CER = ceramic clothes condition

TABLE 2 - Minimal detectable change and effect size (ES) for total time (minutes) (n=10).

	Total Time (minutes)	% Dif	% Change (beneficial/trivial/harmful)	Result	ES
C	52.3 ± 4.1				
PLA	53.1 ± 5.0	1.4	38 / 60 / 2	Possible	0.17
CER	51.4 ± 3.8	-1.7	0 / 51 / 49	Possible	-0.23

C = control condition;
PLA = placebo condition;
CER = ceramic clothes condition

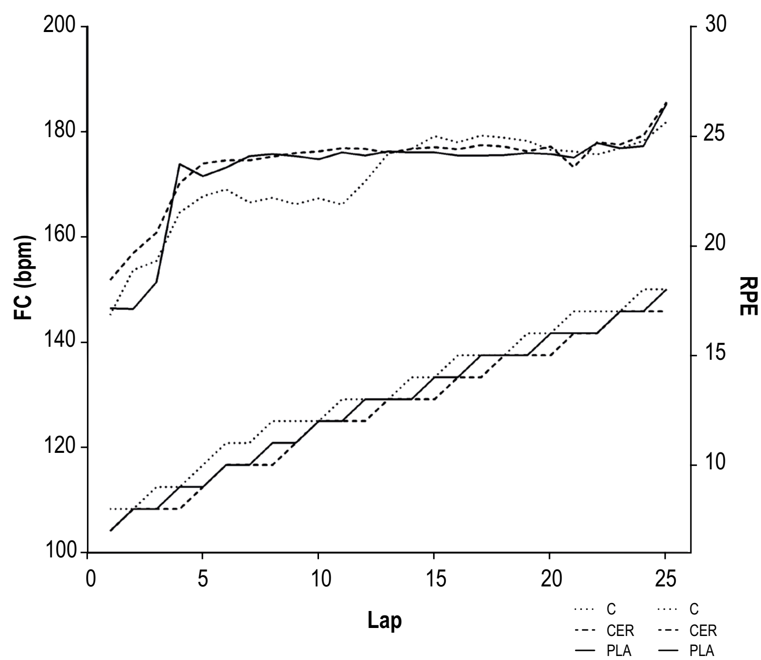

FIGURE 2 – Behavior of HR and RPE through each lap of the 10 km performance in each experimental condition. Registered values for heart rate and rate of perceived exertion for each lap.

TABLE 3 – Minimal detectable change and effect size (ES) for $RPE_{Session}$ (n = 10).

	$RPE_{Session}$ (A.U.)	% Dif	% Change (beneficial/trivial/harmful)	Result	ES
C	425.7 ± 74.8				
PLA	426.6 ± 87.5	-0.3	30 / 37 / 33	Unclear	0.01
CER	440.1 ± 42.5	4.4	54 / 42 / 4	Possible	0.25

$RPE_{Session}$ = rated perceived exertion of the session; C = control condition; PLA=placebo condition; CER = ceramic clothes condition

TABLE 4 – Minimal detectable change and effect size (ES) for muscle soreness (mm) (n = 10).

	DOMS (mm)	% Dif	% Change (beneficial/trivial/harmful)	Result	ES
C	24.4 ± 38.1				
PLA	29.9 ± 34.3	52.0	62 / 26 / 12	Unclear	0.15
CER	43.0 ± 40.8	59.5	61 / 30 / 8	Unclear	0.47

C = control condition; PLA=placebo condition; CER = ceramic clothes condition

TABLE 5 – Blood lactate (LA) concentrations ($mmol·L^{-1}$) (n = 10).

Variables	C	PLA	CER	*P*
$LA_{baseline}$ ($mmol·L^{-1}$)	1.7 ± 1.4	1.3 ± 0.3	1.5 ± 0.5	0.449
$LA_{0\ min}$ ($mmol·L^{-1}$)	6.0 ± 1.2	6.1 ± 1.9	6.2 ± 2.0	0.950
$LA_{3\ min}$ ($mmol·L^{-1}$)	6.6 ± 1.3	6.5 ± 2.0	5.4 ± 2.1	0.181
$LA_{5\ min}$ ($mmol·L^{-1}$)	6.1 ± 1.1	6.0 ± 2.4	5.5 ± 2.1	0.597
$LA_{7\ min}$ ($mmol·L^{-1}$)	5.5 ± 1.9	5.5 ± 2.3	5.0 ± 1.8	0.808
LA_{peak} ($mmol·L^{-1}$)	6.8 ± 1.2	6.7 ± 2.1	6.6 ± 2.1	0.936
$\Delta_{peak\text{-}baseline}$ ($mmol·L^{-1}$)	5.1 ± 1.1	5.4 ± 1.9	5.1 ± 2.0	0.804
$\Delta_{peak\text{-}7\ min}$ ($mmol·L^{-1}$)	1.3 ± 1.3	1.3 ± 0.8	1.6 ± 1.1	0.802
$\Delta_{7\ min\text{-}baseline}$ ($mmol·L^{-1}$)	3.8 ± 1.3	4.2 ± 2.0	3.6 ± 1.7	0.675

C = control condition; PLA=placebo condition; CER = ceramic clothes condition

Discussion

This study aimed to analyze the effect of using bioceramic clothing on the 10 km running performance. We hypothesized that the use of this type of clothing would improve running performance though decreases in HR, RPE, DOMS, improved microcirculation and blood lactate removal profile. The main finding of this study was that the use of bioceramic clothes one hour before and during a 10 km race possibly increased performance, as shown by a decrease in total time when compared with the C and PLA conditions.

Considering the lack of studies involving bioceramic clothes and exercise, we will be discussing our results in light of studies using different forms of phototherapy, such as low-level laser therapy (LLLT) and light-emitting diodes (LED). All these techniques rely on the absorption of light by body tissues, which may cause similar changes in cellular activity[4].

Our results agree with De Marchi et al.[21], who conducted a randomized double-blind placebo-controlled crossover trial with 22 untrained male volunteers, who performed a progressive-intensity running protocol to exhaustion on a treadmill. Low-level laser therapy (LLLT) was applied five minutes before testing and results showed this intervention significantly increased performance (higher time to exhaustion and VO_{2max}) when compared to placebo trials. LLLT also decreased creatine kinase (CK) and lactate dehydrogenase (LDH) activity, decreased oxidative stress and increased antioxidant activity[21]. In line with this, Leung et al.[10] found that FIR has an antioxidant effect on murine myoblast (C2C12) cells, based on cell viability percentages and LDH release assays.

Despite having found significant changes in respiratory parameters such as VO_{2max}, Alves et al.[22] found no modification in performance during an incremental cycle ergometer test performed in LLLT and placebo conditions. The authors point to using a mixed sample (men and women), to the protocol used and to the small quantity of LLLT application points (quadriceps and gastrocnemius) as limitations of the study[22].

Studies demonstrate that the enzymatic activity of all the complexes of the mitochondrial respiratory electron transport chain and of aerobic metabolism-linked enzymes such as succinate dehydrogenase (SDH), nicotinamide adenine dinucleotide (NADH) and CK is enhanced after the application of phototherapy[23-25], assuring a higher rate of ATP synthesis by oxidative metabolism for longer time and greater intensities. Other acute and chronic effects on the mitochondrial structure and function itself, such as: greater biogenesis, density, number, size and membrane potential, also guarantee that phototherapy has an ergogenic effect on aerobic metabolism[26-29]. All these factors could explain the improved performance observed in this investigation.

Although no significant differences were found at any moment for RPE, it tended to be smaller in CER condition. Traditionally, RPE is understood as the integration of peripheral and central signals, which are interpreted by the sensory cortex, producing the perception of effort[30]. Exact physiological mechanisms underlying the RPE are yet to be determined, since it is a complex variable influenced by different extrinsic and intrinsic physiological factors; such as multiple signals coming from the cardiorespiratory and neuromuscular systems[30,31].

The behavior of HR for both conditions was somewhat linear, with a fast increase in the first laps and a small increase in the last lap, which can be explained by the characteristic of the 10 km race – the first and last laps were faster than the remaining of the 10 km performance[32].

Lactate production is a good marker for cell metabolic conditions that induce metabolic acidosis, and blood lactate concentrations are widely used to monitor performance and recovery[33]. Lactate accumulation indicates non-mitochondrial energy production, due to increased exercise intensity[34]. A reduction in lactate concentrations is desirable, because it reflects improved mitochondrial energy production[35]. No statistical changes were detected in lactate concentrations in the present study. A similar result was found in the study of Leal-Junior et al.[36], in which volleyball players were submitted to a fatigue protocol of elbow flexion–extension exercise tested under LLLT and placebo conditions and found no difference in lactate removal rate. The authors attributed this to the experimental protocol used and limitation in the number of irradiated points, and stated that this does not mean that phototherapy is incapable of affecting lactate concentrations and removal[36]; however a greater number of repetitions were performed in LLLT condition, which may indicate a higher lactate production.

The application of light before the effort seems to be crucial to obtain positive effects on blood lactate disappearance[2,3,4,35] because apparently the effect of light on tolerance also improves blood lactate metabolism and the time to achieve peak response. The application of LED after exercise did not ensure the sufficient systemic effect for this response[37], and apparently the use of bioceramic clothing for only one hour before exercise was also not adequate.

According to the qualitative analysis, subjects indicated “Possible” higher $RPE_{Session}$ in the CER condition, which could be justified by the better level of performance presented in that trial. In contrast, Leung et al.[7] study showed that there were tendencies toward decreased tiredness in the bioceramic condition, however, our study involved a 10 km performance while Leung’s consisted in a 30 min run on a treadmill.

Muscle soreness subjective perception is a widely used tool in studies involving muscle damage in humans[38]. Our results showed the CER condition presented higher absolute values of muscle soreness after the 10 km performance, albeit no statistical differences were found. Hausswirth et al.[39] tested the effect of far infrared radiation on recovery after a simulated trail running race. Subjects were submitted to 30 minutes of exposure, and their muscle soreness was evaluated through the 10 cm visual analogue scale. DOMS increased from 0.16 ± 0.32 cm to 6.2 ± 1.9 cm post-race, and statistically significant reductions were observed only 48 h after the recovery intervention[39]. Thus, it is plausible that the use of bioceramic clothes in our study improved muscle soreness in periods when this variable was not being monitored. On the other hand, Borges et al.[40] applied 630 nm LED on the biceps muscle after eccentric exercise bouts and observed that this intervention was sufficient to significantly relieve muscle soreness up to 96 h after LED application. However, the authors emphasize phototherapy was applied to an injured muscle, which might cause different effects than application before potentially effects different from[40].

Leal-Junior et al.[4] analyzed 13 articles to investigate the effects of using phototherapy (LLLT and LED) on exercise and came to the conclusion that the most significant results were found with red or infrared wavelengths applied before exercise, with power outputs between 50 and 200 miliwatts (mW) and doses of 5-6 Joules (J) per point.

Phototherapy and its many forms of application have been largely studied in the last few years. It is not yet clear the amount of energy reflected by the bioceramic fabrics; this depends on body temperature, room temperature and possibly other factors. Albeit small changes were observed in performance in this study, we believe a longer exposure time to the bioceramic materials (such as wearing them overnight) might elicit marked biological effects of aerobic performance.

Our findings indicate that bioceramic clothes might improve running performance, similar to what was observed by other authors with LED or LLLT, which are other, better known, forms of phototherapy. Considering the promising effects of phototherapy reported by other authors[2,4,21,39] and its many forms of application, further studies should be conducted using bioceramic clothes, considering different application durations and factors influencing energy absorption. This ergogenic effect being confirmed, bioceramic clothes could be used instead of LED or LLLT, as they are cheaper and easier to apply.

Resumo

Efeito de roupas de biocerâmica na prova de corrida de 10 km

O objetivo deste trabalho foi analisar os efeitos de roupas de biocerâmica na *performance* de corrida de 10 km. Dez homens jovens (idade 27,9 ± 4,2 anos; estatura 1,8 ± 0,1 m; massa corporal 73,0 ± 7,5 kg; índice de massa corporal (IMC) 23,5 ± 2,3 kg·m^2; percentual de gordura 19,3 ± 4,2 %) participaram do estudo. Os participantes visitaram a pista de atletismo para três corridas de 10 km em 3 condições: utilizando roupas de biocerâmica (CER), placebo (PLA) e utilizando roupas pessoais (C). A ordem dos testes foi randomizada e os sujeitos desconheciam a condição de intervenção. O teste de Friedman ou ANOVA de medidas repetidas foram utilizados para comparar as condições. A Mínima Mudança Detectável e o Tamanho de Efeito também foram calculados. Não foram encontradas diferenças significantes. A análise da Mínima Mudança Detectável sugeriu uma “Possível” redução no tempo para a condição CER (C - 52,3 ± 4,1; PLA – 53,1 ± 5,0; CER 51,4 ± 3,8 minutos). A análise da concentração de lactato mostrou uma remoção mais rápida quando os participantes utilizaram a roupa de biocerâmica. A percepção da dor muscular foi classificada como “Possível” maior na condição CER, e a percepção subjetiva do esforço da sessão ($PSE_{sessão}$) também foi maior nesta condição; essa diferença foi classificada pela análise de Cohen do Tamanho de Efeito como “Pequena” (C – 425,7 ± 74,8; PLA – 426,6 ± 87,5; CER – 440,1 ± 42,5 A.U.). Os resultados sugerem que o uso de roupas de biocerâmica podem melhorar a *performance* de corrida. Mais estudos são necessários para determinar a dosagem ideal, como o tempo de uso e fatores que influenciam a absorção.

Palavras-chave: Biocerâmica; Exercício aeróbio; Radiação infravermelha longa; Lactato; Dor muscular.

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