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Artigo original

Influence of environmental temperature on aerobic performance: physiological and perceptual responses in young adults

Influência da temperatura ambiente no desempenho aeróbio: respostas fisiológicas e perceptuais em adultos jovens

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ABSTRACT

Aim: The present study aimed to analyze the influence of environmental temperature on physiological and perceptual responses on aerobic performance in young adults. **Methods:** Twelve male subjects (23.1 ± 3.3 years; 24.5 ± 3.0 kg/m²), underwent two randomized sessions of incremental cycle ergometer tests in Heat condition (32.7 ± 1.6ºC) and Thermoneutral (22.8 ± 0.6°C) 48-72 hours apart. Peripheral temperature (PT), heart rate (HR), rate of perceived exertion (RPE), Thermal sensation (TS), Feeling Scale (FS), maximum aerobic power (MAP) and exhaustion time (ET) were measured. **Results:** During the Thermoneutral session, ET and MAP were significantly higher when compared to Heat session (20.9 ± 4.1min vs. 19.5 ± 3.5 min; 212.9 ± 43.4 W vs. 198.3 ± 45.6 W; $p < 0.05$). PT and TS were significantly higher in Heat session ($p < 0.01$). However, HR, RPE and FS did not differ between sessions ($p > 0.05$). **Conclusion:** It is concluded that, in young people, aerobic performance is lower in heat, mainly influenced by the increase of PT and TS.

Keywords: exercise test; heat exhaustion; physiology.

RESUMO

Objetivo: O objetivo do presente estudo foi analisar a influência da temperatura ambiente sobre as respostas fisiológicas e perceptuais do desempenho aeróbio em adultos jovens. **Métodos:** Doze indivíduos do sexo masculino (23,1 ± 3,3 anos; 24,5 ± 3,0 kg/m²) realizaram duas sessões randomizadas de testes incrementais em cicloergômetro, na condição Calor (32,7 ± 1,6ºC) e Termoneutro (22,8 ± 0,6°C) com intervalo de 48-72 horas. Foram mensuradas temperatura periférica (TP), frequência cardíaca (FC) percepção subjetiva de esforço (PSE), sensação térmica (ST), valência afetiva (VA), potência aeróbia máxima (Pmax) e tempo de exaustão (TE). **Resultados:** Durante a sessão Termoneutra, o TE e Pmax foram significativamente maiores quando comparados a sessão Calor (20,9 ± 4,1 min vs. 19,5 ± 3,5 min; 212,9 ± 43,4 W vs. 198,3 ± 45,6 W; $p < 0,05$). A TP e ST foram significativamente maiores na sessão Calor ($p < 0,01$). Porém, a FC, PSE e VA não diferiram entre as sessões ($p > 0,05$). **Conclusão:** Conclui-se que o desempenho aeróbio de jovens é menor no calor, influenciado principalmente pelo aumento da TP e ST.

Palavras-chave: teste de esforço; exaustão por calor; fisiologia.

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Introduction

During the practice of aerobic exercise, in a hot environment, physiological changes occur such as dehydration and metabolic overload that can affect cardiovascular function, causing an increase in sympathetic activity and heart rate, modifying the neuromuscular response which could anticipate the fatigue process and impair the performance [1,2]. Thus, the human body uses thermoregulatory pathways of heat exchange with the environment to maintain body temperature in stable physiological parameters [1]. Moreover, changes on exercise intensity and volume can also interfere on cardiovascular load, increasing metabolism and heat production in the human body [2].

The cardiovascular system is one of the main limiters of performance in aerobic exercise under heat stress. The increase of blood flow with cutaneous vasodilation and a higher sweating rate provide serious challenges to the regulation of cardiac output and increase of sympathetic activity [3,4]. Such cardiovascular adjustments follow the increase of skin temperature, leading to the increase of central temperature and resulting in a thermic discomfort and decrease in the voluntary ability to perform exercise [5,6].

Excessive heat production during exercise is one of the main determinants for a good aerobic performance [7]. Thermic stimuli, provoked by the increase of metabolism, body temperature and changes in attention, play a significant role in the modulation of the perception of thermic stress and feelings of pleasure related to exercise [8,9]. These increases in thermic stress can lead to a higher rate of perceived exertion (RPE), which involves several integrated sensations, thus, appearing as another limiter of performance [2,10].

Generally, perceptual responses, beyond physiological responses, can interfere in tolerance to exercise and in adhesion to exercise in heat [11]. Exercising in hot environments can put the body under higher thermic, perceptual and physiological tension than exercising in thermoneutral environments, resulting in a premature onset of fatigue and decreasing the time of tolerance to exhaustion [6-8,12].

In this scenario, maximal incremental test models have been proposed to estimate, evaluate and prescribe aerobic exercise capacity in different individuals. However, little is known about up to which point the temperature of the environment can interfere in the results of these evaluations [13]. Thus, the aim of the present study was to analyze the influence of the temperature of the environment on physiological and perceptual responses to aerobic performance in young adults.

Methods

Study design and ethical aspects

The present study is characterized as a randomized crossed trial [14]. The study was approved by the Research and Ethics Committee of the Federal University of Vale of São Francisco (n° 2.462.622, CAAE: 80612717.3.0000.5196). All participants were informed of the procedures of the research and signed a free informed consent form, as required by the Resolution 466/12 of the Brazilian National Health Council.

Sample's characteristics

Based on the calculation using GPower v. 3.0, considering $\alpha = 0.05$, power = 0.80 and two experimental sessions with a minimum of two measurements in each session, the sample size required for the study was 12 participants, considering the effect size of 0.45 proposed by Cuttell *et al.* [15] for time to exhaustion (TE) and skin temperature.

Thus, the sample was composed by 12 physically active males, aged between 18 to 30 years (23.1 ± 3.3 years; 24.5 ± 3.0 kg/m²) (Figure 1). The exclusion criteria were any cardiometabolic disease or dysfunctions; having any bone, joint or muscle impairments that could compromise the physical integrity and the participation in the study; using any drugs related to blood pressure control or diabetes mellitus; and not showing up to the experimental sessions

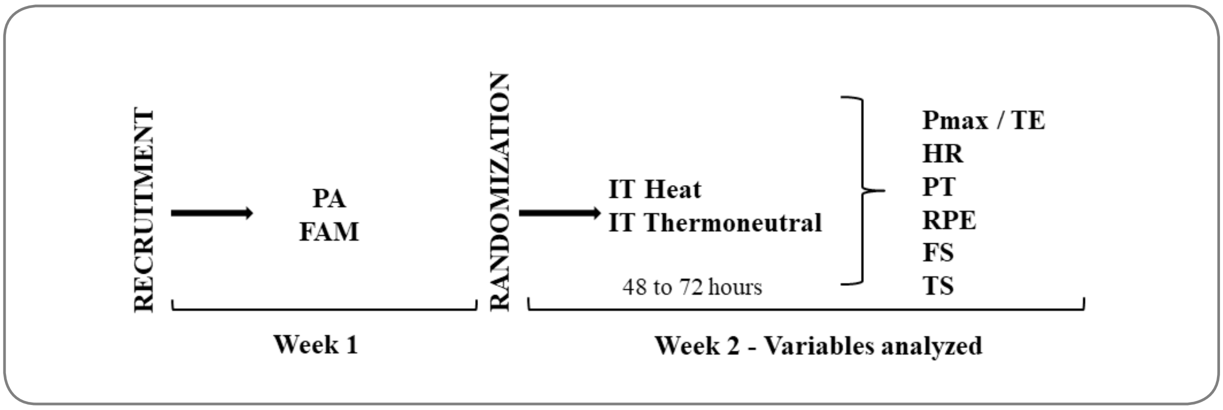
General procedures

The participants were invited to attend the laboratory for three visits in a period of two weeks (Figure 2). In the first week/visit the participants answered the Physical Activity Readiness Questionnaire (PAR-Q) [16], the short version of the International Physical Activity Questionnaire (IPAQ) [17], underwent anthropometric measurements and performed a familiarization session of the incremental test (IT) on the cyclergometer. In the second week/visits a cross-randomization (Microsoft Excel) was carried out, in which, initially, half of the participants were assigned to the Heat session (32.7 ± 1.6ºC) and the other half to the Termoneutro session (22.8 ± 0.6 ° C), later the reverse procedure was applied, with a difference of 48-72 hours between sessions (Figure 2). All sessions were performed during the morning. The ambient temperature and the relative humidity of the air were monitored by a thermohygrometer (Impac, IP-780). The sessions were standardized in the same room, and the room temperature was reached using an air conditioning unit (RHEEM - 9000 BTUs) and a heater (CONSUL - 1500W) adjusting to the desired temperature.

Tests and aerobic sessions

In the second week of the study the participants performed two randomized IT sessions in a heated (32.7 ± 1.6 ºC) and thermoneutral (22.8 ± 0.6 ºC) environment with an interval of 48-72 hours. The IT protocol was performed on a cyclergometer (Cefis, Biotec 2100, Brazil). The test began with 35 watts (W) of power and a speed of 70 rotations per min (rpm), with increments of 35W every 3 min (stages) until maximal voluntary exhaustion or not being able to maintain the pre-determined speed at 70 rpm [13]. At the end of each session, time to exhaustion (TE) and maximal aerobic power (Pmax) were registered. In both IT sessions the following physiological and perceptual variables were analyzed: coloration and specific gravity of urine (SGU), peripheral temperature (PT), heart rate (HR), thermal sensation (TS), rate of perceived exertion (RPE) and feeling scale (FS).

The participants were advised to refrain from tobacco, caffeine and alcohol use or intake, as well as not to perform physical activity in the 24 hours preceding the sessions. In order to standardize the participants' diets before IT, the subjects were instructed, by a qualified nutritionist, to report their food consumption in the 24 hours preceding the first session in order to replicate the same diet 24 hours before the second session.



PA = physical evaluation; FAM = familiarization; IT = incremental test; Pmax = maximal aerobic power; TE = time to exhaustion: HR = heart rate; PT = peripheral temperature; RPE = rate of perceived exertion; FS = feeling scale; TS = thermal sensation

Figure 1 - Experimental design of the study

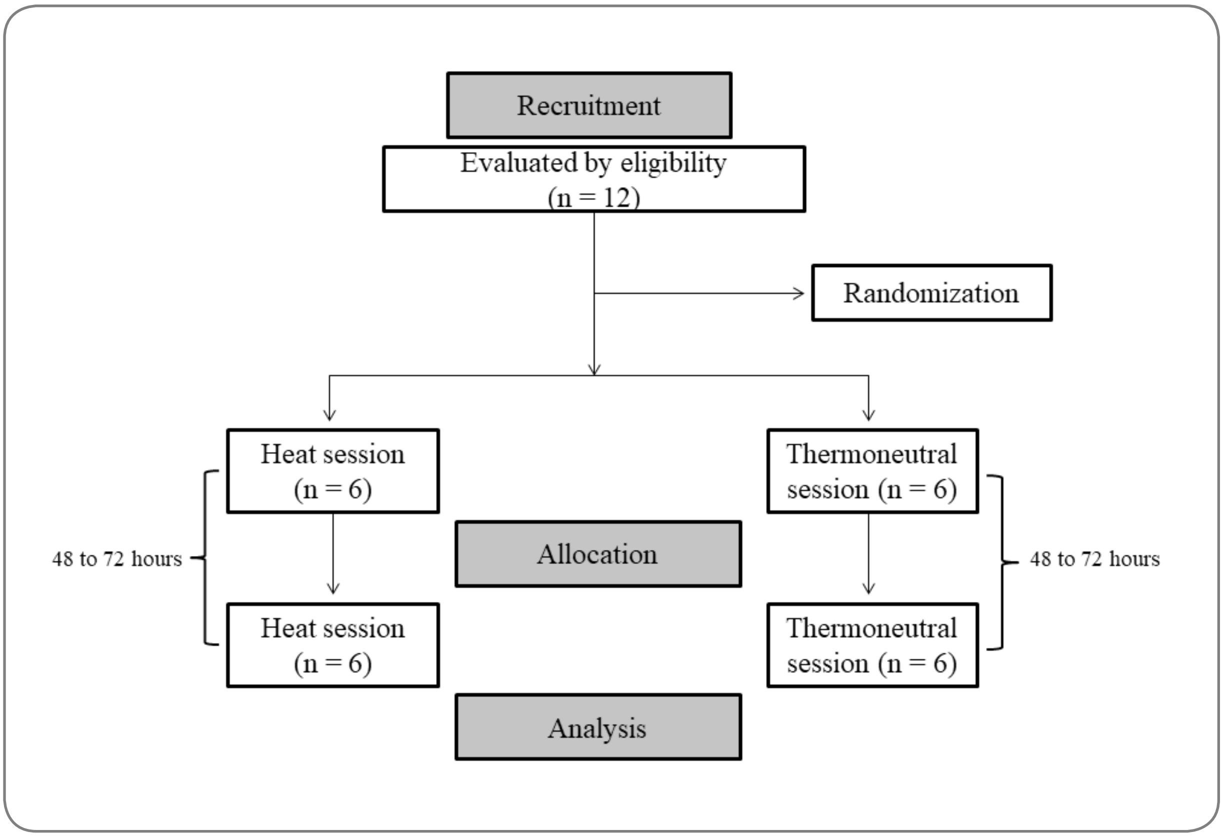


Figure 2 - Flowchart of the study

Heart rate and peripheral temperature

Heart rate (HR) was measured using a heart rate monitor (RS800CX Polar®, ElectroOy, Finland) [18] during 10 min at rest and at the last minute of each 3 min stage of IT, in both conditions. Peripheral temperature (PT) was also measured during 10 min at rest and at the last minute of the 3 min stages. The analysis of temperature was obtained from four different parts of the body (chest, arm, thigh and leg) through skin thermistors, attached to the participants using a transparent waterproof adhesive, connected to a teletermometer [15] (model THERM 37904, Viamed Ltd, West Yorkshire, United Kingdom), as proposed by Ramanathan [19].

Scale of coloration and specific gravity of urine

When arriving in the laboratory, the participants were asked to drink 0.5L of water, 60 min before sessions. Thus, the participants provided a sample of urine in order to measure the specific gravity of urine (SGU), using a portable refractometer (Biobrix, Model 301), which was previously calibrated adjusting the scale with deionized water. The analysis of the scale of coloration of the urine was also performed, in which values higher that 1.020 g•ml^{-1} (SGU) and coloration higher than 5 indicated levels of dehydration [1,20]. These variables were measured before each IT session to evaluate the hydration level of each participant.

Perceptual variables

Before the IT sessions a verbal or memory anchorage of the RPE [21], FS [22] and TS [23,24] scales was performed. The perceptions were analyzed during 10 min at rest and at the last 20 seconds of each 3 min stage of the IT sessions.

ST was measured using a seven point scale in which the participant stated their sensation according to the values -3 (very cold), -2 (cold), -1 (slightly cold), 0 (neutral = comfort), +1 (slightly hot), +2 (hot) and +3 (very hot), with the possibility of choosing intermediary values [23-25].

The FS in quantified from +5 to -5, corresponding, respectively, to two opposite descriptors of the feeling during exercise (+5 = very good and -5 = very bad). In addition to those, the scale also presents intermediary descriptors: +3 = good; +1 = reasonably good; 0 = neutral; -1 = reasonably bad; -3 = bad [22,26].

Lastly, RPE was measured using a perceived exertion scale (from 6 to 20 points), in which 7 corresponds to the lowest exercise intensity and 19 to the highest [21].

Statistical analysis

Data was analyzed using descriptive statistics (mean and standard deviation). Shapiro Wilk's test was performed in order to verify data normality. Since data normality was confirmed, inferential statistics were performed using two-way repeated measures ANOVA with Bonferroni post hoc to compare between and within values of both sessions (heat and thermoneutral). The level of significance adopted was $p < 0.05$ and the effect size was reported using eta squared values (η^2) (SPSS, version 22.0).

Results

Table I presents the control variables (temperature of environment, relative air humidity, specific gravity of urine and urine coloration) in both sessions. Results showed that temperature of environment was significantly higher in the heat session when compared to thermoneutral ($p < 0.01$). Relative air humidity, SGU and urine coloration scale were similar in both sessions. Lastly, TE and Pmax were higher in the thermoneutral session when compared to heat ($p < 0.05$).

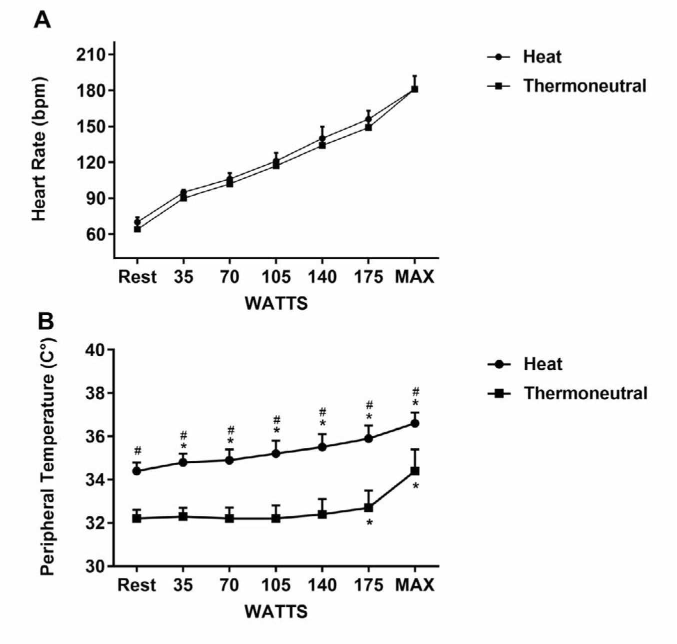
Table I - Comparison of control and performance variables during the maximum incremental aerobic test with different environment temperatures

	Heat	Thermoneutral	P value
Temperature of environment (Cº)	32.7 ± 1.6	22.8 ± 0.6	<0.01*
Relative air humidity (%)	34.8 ± 3.1	36.8 ± 3.8	0.278
Specific gravity of urine (g/ml)	1.020 ± 0.009	1.022 ± 0.009	0.636
Coloration of urine	3.8 ±1.4	4.1 ± 1.2	0.586
Time to exhaustion (min)	19.5 ± 3.5	20.9 ± 4.1	<0.01*
Maximal aerobic power (Pmax)	198.3 ± 45.6	212. 9 ± 43.4	0.017*

*p<0.05

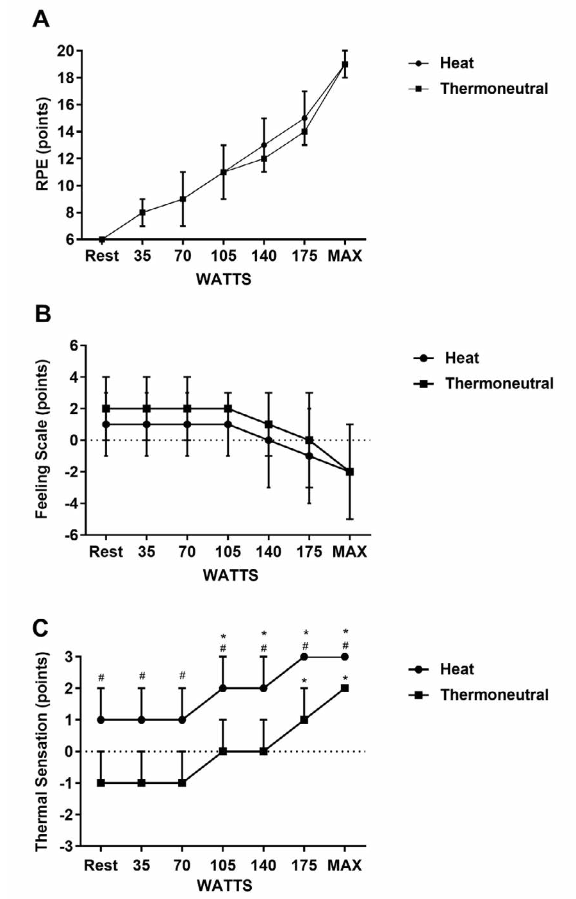
When comparing HR and PT temperature in both sessions (Figure 3), statistically significant differences were found for HR when comparing different stages of the same session with values at rest ($p < 0.01$; $\eta^2 = 0.961$). However, no differences were found when comparing stages between sessions ($p = 0.83$; $\eta^2 = 0.021$). PT, on the other hand, presented significant differences to rest in stages of the same session ($p < 0.01$; $\eta^2 = 0.891$) as well as between stages of both sessions ($p < 0.01$; $\eta^2 = 0.398$).

Statistically significant differences were also found regarding the perceptual variables (RPE, FS and TS) during the sessions (Figure 4). RPE showed differences when comparing different stages of the same session to values at rest ($p < 0.01$; $\eta^2 = 0.944$), however, no differences were found when comparing stages between sessions ($p = 0.40$; $\eta^2 = 0.045$). Likewise, FS presented statistical differences when comparing stages to rest in the same session ($p < 0.01$; $\eta^2 = 0.398$), while no differences were found when comparing stages between sessions ($p = 0.850$; $\eta^2 = 0.020$). Lastly, the analysis of TS showed differences when comparing stages to rest in the same session ($p < 0.01$; $\eta^2 = 0.810$) and between sessions ($p < 0.01$; $\eta^2 = 0.199$).



MAX = maximum watts; *p < 0.05 when compared to rest in the same session; #p < 0.05 when compared to the same stage in the thermoneutral session

Figure 3 - Heart rate responses and peripheral temperature during maximum aerobic incremental test in different environment temperatures



RPE = rate of perceived exertion; MAX = maximum watts; *p < 0.05 when compared to rest in the same session; #p < 0.05 when compared to the same stage in the thermoneutral session

Figure 4 - Rate of perceives exertion, affective valence and thermal sensation responses during maximum aerobic incremental test in different environment temperatures

Rev Bras Fisiol Exerc 2021;20(3):335-345

Discussion

The present study aimed to analyze the influence of environment temperature on the physiological and perceptual responses to aerobic performance in young adults. In order to do so, the temperature of the environment and levels of hydration of the participants were controlled (Table I). The main findings showed lower aerobic performance in a heated environment when compared to a thermoneutral one, with lower TE and Pmax after IT (Table I). Moreover, when analyzing the physiological responses, it was possible to observe that the participants' PT was higher in the heated session when compared to thermoneutral. However, HR did not differ between sessions (Figure 3). Lastly, perceptual responses also indicated a higher TS in the heated session when compared to thermoneutral, which did not occur to RPE and FS when comparing sessions (Figure 4).

Studies show a decrease in aerobic performance when exercise is performed in high temperatures [4,6,27]. Possible mechanisms associated to this are related to alterations caused by the stress induced to the central nervous system and skeletal muscle functions, which could lead to a higher relative exercise intensity, increase of cortisol levels and decrease in maximal oxygen uptake [4,10]. Agreeing with literature, the present study showed that during a maximum aerobic IT in heat, TE and Pmax were lower than when compared to a thermoneutral session. However, the exercise protocol used differs from previous studies, since the IT is performed with incremental loads, causing an increase in intensity and a short execution time. Thus, cooling strategies have been proposed in order to minimize the effects of heat related to exercise, such as controlling hydration and wearing cooling vests [1,15].

Changes in exercise intensity and climate conditions can interfere in the cardiovascular load, since they modify the dissipation of heat and promote an increase in HR [2]. Natera *et al.* [28] verified the influence of environment in HR responses during an incremental test in rugby athletes and found higher HR values in an outdoor environment (34 ºC, 64.1% air humidity) than indoors (22 ºC, 50% air humidity). These results do not agree with the found in the present study, since HR was similar in both IT sessions. However, it is important to highlight that cardiovascular adaptations can suffer interferences of several factors beyond environmental conditions, such as exercise intensity and duration [3]. Thus, it is suggested that the short duration of the IT sessions performed in the present study, as well as the progressive increase of intensity, may have masked differences in HR between sessions.

The results of the present study also showed that during the maximum aerobic IT in heat session, PT was higher in all stages than when compared to thermoneutral (Figure 3). According to literature, performing exercise in hot environments leads to an increase in body temperature. Therefore, thermoreceptors located throughout the body detect changes in temperature and transmit this information through afferent channels to the brain, altering the control of sensation and thermic comfort and influencing the decrease of aerobic performance in heat [6]. Changes in TS are results of dynamic increases and decreases in skin temperature during exercise [7]. This corroborates with the present study's findings, in which throughout the whole maximum aerobic IT in heat, TS remained higher than when compared to thermoneutral (Figure 4). The increase in PT and TS demonstrates greater sensitivity to being influenced both by the intensity of the exercise (increased load) and by the ambient temperature (Heat and Thermoneutral), which did not occur with HR, RPE and FS, and which did not differ between sessions.

The activation of peripheral thermo sensors can also result in a conscious change of the subjective thermal perception, which can include affective components related to pleasure [7]. However, in the present study, FS did not differ between sessions (Figure 4). In this scenario, Cheung *et al.* [8] verified that exercise in heat under a constant workload resulted in higher cardiovascular tension, promoting a higher thermic discomfort and changes in effort perception. These results differ from the ones of the present study, since no differences were found in RPE between sessions, as the tests were performed with progressive intensities (Figure 4). Cleary *et al.* [29] demonstrated that cooling strategies can modify thermal perception without altering RPE, such a tool is widely used as a control variable for exercise intensity [30]. Thus, these two variables, FS and RPE, can also singly respond to aspects related to exercise temperature and intensity, and intensity/load factor can overlap and directly influence your responses.

Given the exposed, it is recommended that the evaluation and prescription of aerobic training, through maximum aerobic IT, reflect the environment in which exercise is performed. So that professionals be alert that possible changes in evaluations are derived from the temperature of the environment, compromising the results of the prescription. Such information can enhance the concept of exercise prescription related to health and performance, and improve the work of physical education and sports professionals [31].

Conclusion

Young adult physically active males presented lower performance during maximum aerobic IT in heat when compared to a thermoneutral condition. Such performance was influenced by an increase in PT and TS in heat. However, HR, RPE and FS responses were not different between conditions. In this scenario, the importance of controlling environment temperature is highlighted when it comes to a good aerobic exercise prescription and evaluation.

Conflict of interest
No conflicts of interest have been reported for this article.

Financing source
There were no external sources of funding for this study.

Authors' contributions

Conception and design of the research: Araujo FS, Pereira HAL, Moraes JFVN. **Data collection:** Pereira HAL, Santos GA, Santos GLLS. **Statistical analysis and data interpretation:** Araujo FS, Moraes JFVN. **Writing of the manuscript:** Araujo FS, Pereira HAL. **Critical review of the manuscript:** Santos GA, Santos GLLS. **Final revision of the manuscript:** Araujo FS, Moraes JFVN.

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