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Victor Hugo Pereira Franco

Respostas fisiológicas e perceptuais com ênfase na termorregulação  
durante e após uma corrida de longa duração (6 horas)

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Orientador: Prof. Dr. Jorge Roberto Perroux  
de Lima

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## RESUMO

**INTRODUÇÃO:** A termorregulação é um mecanismo fisiológico essencial para a manutenção da temperatura corporal dentro de limites estreitos, mesmo diante de variações ambientais. Durante o exercício físico, especialmente em corridas de longa duração, a produção de calor metabólico aumenta significativamente devido ao trabalho muscular intenso. Compreender como esses processos termorregulatórios atuam durante o esforço prolongado é fundamental para garantir a segurança dos atletas, otimizar o desempenho esportivo e prevenir complicações associadas ao estresse térmico. **OBJETIVO:** Analisar as respostas fisiológicas, metabólicas e perceptuais durante e após uma corrida contínua de 6 horas, com ênfase na termorregulação e foco específico na dinâmica da temperatura da pele ao longo do esforço prolongado. **METODOLOGIA:** A tese foi estruturada em formato de três artigos. Artigo 1: Correlação entre a distância percorrida, temperatura corporal e esforço percebido durante uma corrida de longa duração. Objetivos: (1) avaliar longitudinalmente a dinâmica da temperatura da pele do corpo e da coxa e (2) avaliar suas correlações temporais com a distância percorrida e a percepção do esforço antes e após 2h, 4h e 6h de corrida. Artigo 2: Análise das respostas cardiovasculares, metabólicas e perceptuais antes, durante e após uma corrida de longa duração. Objetivo: analisar as respostas cardiovasculares, metabólicas e perceptuais em corredores masculinos treinados antes, durante e depois de uma corrida contínua de seis horas. Trinta e nove soldados de elite do sexo masculino (idade:  $31,4 \pm 5,7$  anos) participaram de uma corrida contínua de 6 horas realizada em uma pista de 400 metros. Os participantes foram categorizados retrospectivamente em três grupos, de acordo com a distância total percorrida: submaratonistas (<40 km), maratonistas (40–44 km) e ultramaratonistas (>44 km). As variáveis avaliadas incluíram indicadores fisiológicos (temperatura da pele, frequência cardíaca, pressão arterial e massa corporal), marcadores metabólicos (análise urinária) e respostas perceptuais (dor, sede, sensação térmica, umidade da pele, conforto térmico e percepção de esforço). As coletas de dados foram realizadas em oito momentos distintos: 24 horas e 1 hora antes da corrida (PRE24h e PRE1h), durante o esforço (2h e 4h), e após o término da prova (6h, POST1h, POST24h e POST48h). **RESULTADOS:** Artigo 1: Todos os grupos apresentaram aumento da temperatura no POST6h em comparação ao PRE [ $1,9$  ( $0,1; 3,7$ ) °C;  $p=0,037$ ] e no POST2h [ $2,3$  ( $0,7; 4,0$ ) °C;  $p=0,002$ ]. Para a região anterior da coxa, houve diferença significativa entre o PRE e o POST2h em comparação ao POST4h e o POST6h ( $p \leq 0,001$  para todas as comparações). A distância total apresentou correlação positiva com a temperatura da coxa direita e esquerda no POST6h ( $p \leq 0,036$  para todas as

comparações) e a percepção do esforço no POST4h e no POST6h ( $p \leq 0,008$  para todas as comparações). A temperatura corporal (Body Surface Temperature - BST) no POST4h apresentou correlação inversa com a distância total ( $p \leq 0,001$ ). Artigo 2: Ultramaratonistas apresentaram maiores reduções na massa corporal, respostas mais elevadas da frequência cardíaca e aumento do desconforto em múltiplas respostas perceptuais. Diversas variáveis permaneceram significativamente alteradas mesmo 48 horas após o exercício, particularmente no grupo da ultramaratona. A análise de medidas repetidas revelou efeitos temporais significativos ( $p < 0,001$ ) para a maioria das variáveis e efeitos de interação indicando diferenças no nível de desempenho nos perfis de recuperação. **CONCLUSÕES:** A percepção de esforço (RPE) no POST4h e no pós-corrida, bem como a temperatura da coxa no POST4h, emergiram como preditores significativos da distância percorrida. O monitoramento dessas variáveis pode auxiliar atletas e treinadores na definição de estratégias de ritmo mais eficazes e na elaboração de protocolos de hidratação que evitem elevações excessivas da temperatura corporal. Distâncias maiores foram associadas a um esforço fisiológico e perceptual mais intenso e prolongado, reforçando a importância de estratégias de recuperação individualizadas após esforços de ultra endurance. A integração de marcadores cardiovasculares, metabólicos e perceptuais fornece uma visão abrangente sobre possíveis mecanismos de fadiga e recuperação, com implicações práticas relevantes para o treinamento de endurance e a gestão do desempenho esportivo.

**Palavras-chave:** Termorregulação; Termografia Infravermelha; Temperatura da Pele; Percepção; Corrida.

## ABSTRACT

**INTRODUCTION:** Thermoregulation is an essential physiological mechanism responsible for maintaining core body temperature within safe limits, even under varying environmental conditions. During physical exercise, particularly in long-distance running, heat production increases significantly due to muscular work. Understanding how these thermoregulatory processes function during prolonged exertion is crucial to ensuring athlete safety, optimizing sports performance, and preventing complications related to thermal stress. **OBJECTIVE:** To analyze the physiological, metabolic and perceptual responses during and after a 6-hour running, with an emphasis on thermoregulation and specific focus on the dynamics of skin temperature throughout prolonged exertion. **METHODS:** This thesis was structured in three scientific articles. Article 1: Correlation between distance covered, body temperature and perceived exertion during a long-term endurance running. Objectives: (1) to longitudinally assess body and thigh temperature dynamics and (2) to evaluate their temporal correlations with the distance covered and perceived exertion before and after 2, 4, and 6 hours of running. Article 2: Analysis of cardiovascular, metabolic, and perceptual responses before, during, and after a long-term endurance running. Objective: To analyze cardiovascular, metabolic, and perceptual responses in trained male runners before, during, and after six-hour long-term endurance running, with emphasis on performance-based differences and recovery dynamics up to 48 hours post-running. Thirty-nine male elite soldiers (age:  $31.4 \pm 5.7$  years) participated in a six-hour long-term endurance running on a 400-m track. Participants were retrospectively categorized into three groups according to the total distance covered: submarathoners (<40 km), marathoners (40–44 km), and ultramarathoners (>44 km). The variables evaluated included physiological indicators (skin temperature, heart rate, blood pressure, and body mass), metabolic markers (urinary analysis), and perceptual responses (pain, thirst, thermal sensation, skin moisture, thermal comfort, and perceived exertion). Data collection was performed at eight distinct time points: 24 h and 1 h before the race (PRE<sub>24h</sub> and PRE<sub>1h</sub>), during the effort (2h, 4h and 6h), and after the end of the race (POST<sub>1h</sub>, POST<sub>24h</sub>, and POST<sub>48h</sub>). **RESULTS:** Article 1: All groups showed an increased temperature at POST<sub>6h</sub> vs. PRE [1.9 (0.1; 3.7) °C;  $p=0.037$ ] and POST<sub>2h</sub> [2.3 (0.7; 4.0) °C;  $p=0.002$ ]. For anterior thigh there was a significant difference between PRE and POST<sub>2h</sub> vs. POST<sub>4h</sub> and POST<sub>6h</sub> ( $p \leq 0.001$  for all comparison). Total distance showed positive correlation between with the temperature of the right and left thigh POST<sub>6h</sub> ( $p \leq 0.036$  for all comparison) and RPE at POST<sub>4h</sub> and POST<sub>6h</sub> ( $p \leq 0.008$  for all comparison). Body surface temperature (BST) at POST<sub>4h</sub> showed inverse correlation with

total distance ( $p \leq 0.001$ ). Article 2: Ultrarunners showed greater reductions in body mass, higher heart rate responses, and increased discomfort across multiple perceptual domains. Several variables remained significantly altered even 48 hours post-exercise, particularly in the ultramarathon group. Repeated-measures analysis revealed significant time effects ( $p < 0.001$ ) for most variables, and interaction effects indicating performance-level differences in recovery profiles. **CONCLUSIONS:** Perceived exertion (RPE) at POST4h and post-race, as well as thigh temperature at POST4h, emerged as significant predictors of the total distance covered. Monitoring these variables can assist athletes and coaches in developing more effective pacing strategies and hydration protocols aimed at preventing excessive increases in core temperature. Greater distances were associated with more intense and prolonged physiological and perceptual strain, highlighting the importance of individualized recovery strategies following ultra-endurance efforts. The integration of cardiovascular, metabolic, and perceptual markers provides a comprehensive understanding of fatigue and recovery mechanisms, with practical implications for endurance training and performance management.

**Keywords:** Thermoregulation; Infrared Thermography; Skin Temperature; Perception; Running.

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## LISTA DE ABREVIATURAS E SIGLAS

AI - anterior inferior  
ALT – anterior left thigh  
ART – anterior right thigh  
AS - anterior superior  
BMI - body mass index  
BRIPAC - Military Base of Paratroopers "Príncipe" (Madrid)  
BST - Body Surface Temperature (temperatura da superfície corporal)  
DBP – Diastolic Blood Pressure  
HR – heart rate  
IRT - Infrared Thermography  
PI – posterior inferior  
PLT – posterior left thigh  
PS – posterior superior  
PRE24h – 24 horas antes da corrida  
PRE1h – 1 hora antes da corrida  
PRT – posterior right thigh  
PRS - Perceived Recovery Status Scale  
POST2h – 2 horas após o início da corrida  
POST4h – 4 horas após o início da corrida  
POST6h – 6 horas após o início da corrida (término da corrida)  
POST1h – 1 hora após o término da corrida  
POST24h – 24 horas após o término da corrida  
POST48h – 48 horas após o término da corrida  
ROI – region of interest  
RPE - rating of perceived exertion  
SBP - Systolic Blood Pressure  
SD - standard deviation  
TSk – skin temperature  
USG - Urine Specific Gravity  
XTSk - mean skin temperature of each original ROI

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## INTRODUÇÃO

A termorregulação é um mecanismo fisiológico fundamental para a manutenção da temperatura corporal dentro de estreitos limites, mesmo diante de variações ambientais. Durante o exercício físico, especialmente em corridas de longa duração, a produção de calor metabólico aumenta substancialmente em função das contrações musculares. Para manter a homeostase térmica, o organismo ativa uma cascata de respostas vasomotoras e cardiovasculares que favorecem a dissipação de calor, como o aumento do fluxo sanguíneo cutâneo e a evaporação do suor (Cheuvront & Haymes, 2001; González-Alonso et al., 2000; Wendt et al., 2007). No entanto, em situações nas quais a dissipação é insuficiente, pode haver acúmulo de calor corporal, resultando em queda de desempenho e maior risco de complicações como desidratação e hipertermia (Kenefick et al., 2007; Roberts et al., 2023).

Corridas de longa duração, como maratonas e ultramaratonas, são frequentemente realizadas sob ampla variação de condições ambientais (calor, umidade, vento e chuva) que interagem com a intensidade e a duração do exercício. Nas últimas décadas, esse tipo de prova tem se popularizado entre corredores, o que implica um aumento no número de indivíduos expostos a cenários extremos de estresse térmico, muitas vezes sem aclimatação ou estratégias adequadas de monitoramento (Bouscaren, Millet & Racinais, 2019; Ebi et al., 2021; Hoffman & Wegelin, 2009; Scheer, 2019).

Apesar dos avanços científicos, a literatura ainda é escassa no que se refere à avaliação longitudinal das respostas fisiológicas e perceptuais durante e após corridas de longa duração. A maioria dos estudos concentra-se na temperatura central e em variáveis sistêmicas, negligenciando o comportamento da temperatura da pele que é um componente-chave para compreender os mecanismos periféricos de dissipação de calor. Além disso, os estudos sobre termorregulação e corrida usam métodos muito diferentes entre si, o que dificulta comparar os resultados e chegar a recomendações claras e aplicáveis (Chudecka & Lubkowska, 2015).

O uso integrado de marcadores fisiológicos (como temperatura da pele, frequência cardíaca, pressão arterial, massa corporal, análise urinária) e respostas perceptuais (como dor, sede, conforto térmico e esforço) tem se mostrado promissor para o monitoramento da carga interna. Escalas de percepção fornecem acesso direto à experiência do atleta e são particularmente úteis em contextos de campo, por sua praticidade e sensibilidade às variações no estado fisiológico (Borg, 1982; Kenttä & Hassmén, 1998; Costa et al., 2019). Contudo, ainda são raras as investigações que

avaliam simultaneamente essas variáveis em diferentes perfis de corredores e em múltiplos momentos do processo de recuperação.

Diante dessas lacunas, esta tese foi estruturada no formato de dois artigos científicos que abordam dimensões complementares da termorregulação em contextos de corrida prolongada. O Artigo 1 investiga a correlação entre a distância percorrida, a temperatura corporal e a percepção de esforço durante uma corrida de seis horas de duração, com mensurações realizadas antes, durante e imediatamente após o esforço. O Artigo 2 analisa as respostas cardiovasculares, metabólicas e perceptuais antes, durante e até 48h após a mesma corrida de seis horas, comparando três grupos (sub-maratonistas, maratonistas e ultramaratonistas), categorizados pela distância total percorrida.

Em conjunto, os dois estudos contribuem para o avanço do conhecimento sobre os mecanismos fisiológicos e perceptuais envolvidos na termorregulação durante provas de ultraendurance. Os resultados podem embasar o desenvolvimento de estratégias mais eficazes de ritmo, hidratação e recuperação individualizada, com implicações práticas para o treinamento, a prevenção de distúrbios térmicos e a segurança de atletas expostos a ambientes severos.

Por tudo isso, o objetivo central dessa tese foi analisar as respostas fisiológicas, metabólicas e perceptuais durante e após uma corrida contínua de 6 horas, com ênfase na termorregulação e foco específico na dinâmica da temperatura da pele ao longo do esforço prolongado.

## ARTIGO 1 – Correlation between distance covered, body temperature and perceived exertion during a long-term endurance running

Este artigo será submetido ao *International Journal of Sports Physiology and Performance* (Qualis A1).

### Abstract

**Background:** Despite the increase in the number of ultra-distance runners and runners, there are few studies that analyze thermal measurements in these runners.

**Aims:** Assess changes in total body and localized thigh skin temperature before, during, and after a 6-hour long-term endurance in recreational athletes and determine whether total running distance correlates with the rating of perceived exertion (RPE), total body and thigh skin temperature over the running.

**Methods:** For this, 39 male military soldiers performed 6-hour running. The participants were separated in 3 groups according total running distance: (a) Ultramarathon ( $\geq 44$  km); (b) Marathon (between 40-44 km; (c) Sub-Marathon  $< 40$  km. Before and each 2 km we measured the skin temperature (TSk - °C), time (min.) and RPE (a.u.).

**Results:** All groups showed an increased temperature at POST<sub>6h</sub> vs. PRE [1.9 (0.1; 3.7) °C;  $p=0.037$ ] and POST<sub>2h</sub> [2.3 (0.7; 4.0) °C;  $p=0.002$ ]. For Anterior thigh there was a significant difference between PRE and POST<sub>2h</sub> vs. POST<sub>4h</sub> and POST<sub>6h</sub> ( $p \leq 0.001$  for all comparison). Total distance showed positive correlation between with the temperature of the right and left thigh POST<sub>6h</sub> ( $p \leq 0.036$  for all comparison) and RPE at POST<sub>4h</sub> and POST<sub>6h</sub> ( $p \leq 0.008$  for all comparison). BST at POST<sub>4h</sub> showed inverse correlation with total distance ( $p \leq 0.001$ ).

**Conclusion:** RPE at POST<sub>4h</sub> and post-race, BST post-race, and thigh temperature at POST<sub>4h</sub> emerged as predictors of the distance covered. Monitoring these variables could assist athletes and coaches in pacing strategies to optimize performance, as well as establishing hydration protocols to prevent excessive increases in body temperature.

**Keywords:** Infrared thermography; athletic performance; ultramarathon; perceived of exertion; thermal sensation; human performance.

## 1. Introduction

Ultramarathons are defined as running events exceeding the standard marathon distance (42,195 km). Over the past decade, these races have surged in global popularity, marked by a rise in both participation rates and event diversity (Berger et al., 2024). Modern ultramarathons vary widely in format, ranging from single- to multi-day competitions, with distances spanning 45 km to over 5,000 km or time-based durations (i.e., 6 to 48-h). They are held across diverse terrains, including roads, tracks, treadmills, and mountainous trails (Balducci et al., 2017; Berger et al., 2021). This growth has increased scientific interest in understanding the physiological and performance determinants specific to ultramarathon athletes. Preliminary evidence suggests that key factors, such as anaerobic threshold, running economy, and maximal aerobic capacity, may influence performance similarly to marathon running (Alves et al., 2022; Knechtle & Nikolaidis, 2018; Matta et al., 2020). However, due to limited empirical research, these associations remain hypothetical and warrant further investigation.

Ultramarathons conducted in extreme heat challenge athletes' thermoregulatory systems, increasing reliance on cutaneous blood flow and sweat production to dissipate internal heat, a critical physiological demand for sustaining performance (Byrne et al., 2022; Valentino et al., 2016). When ambient temperatures exceed skin temperature, the body absorbs environmental heat, exacerbating the need to offload excess thermal load. Prolonged elevation of cutaneous blood flow places significant cardiovascular strain, as the body balances competing demands for oxygenation and cooling (Byrne et al., 2022). In such conditions, the rate of perceived exertion (RPE) emerges as a key pacing strategy (Micklewright et al., 2009). RPE integrates psychological factors and prior athletic experience, offering a holistic gauge of psychophysiological stress. Its simplicity and adaptability further enhance its utility, enabling practical, economical monitoring during ultramarathons (Billat et al., 2022).

About the thermal measurements and control in sports, infrared thermography presents itself as a very useful tool and can be used before, during and after training and competitions (Cabizosu et al., 2024; Gutiérrez-Vargas et al., 2017). Using infrared thermography (IRT), it is possible to establish the specific thermal profile of each athlete and thus have a map with the thermal characteristics considered normal for each body region (Moreira et al., 2017). In addition, studies concluded that the use of IRT during competitions and training in hot conditions (such as ultramarathon) help prevent hyperthermia, helping to control body cooling procedures (Fernandes et al., 2016; Marins

et al., 2015; (Racinais et al., 2021). Previous research has concluded that skin temperature (TSk) during low-intensity aerobic exercise tends to fall, but quickly rises back to normal values after exercise (Drzazga et al., 2018). However, to the best of our knowledge, no study has analyzed skin temperature during long term endurance exercise such as the ultramarathon. IRT serves as a versatile, non-invasive tool for monitoring ultramarathon athletes across training and competition phases. By capturing real-time thermal data, IRT facilitates continuous tracking of thermoregulatory dynamics (from localized limb responses to whole-body adaptations) under varying exercise intensities (Romão et al., 2021). This technology enables researchers to quantify and generate detailed thermal maps across extensive anatomical regions, offering insights into heat distribution and dissipation mechanisms (Belinchón-deMiguel et al., 2024). The ability of IRT to deliver objective, real-time physiological feedback without interfering with performance makes it particularly valuable for optimizing athlete management in extreme endurance contexts (de Andrade Fernandes et al., 2016).

Investigations involving ultramarathon athletes are critical to determine whether thermoregulatory patterns observed in short-duration endurance running (such as transient skin TSk fluctuations) persist under prolonged effort. Current evidence remains limited regarding TSk behavior, performance determinants, and thermoregulatory response during ultramarathons, particularly following the cumulative physiological stress induced over the track (Vernillo et al., 2017). To the best of our knowledge, only one investigation monitored thermographic responses in 160 km ultramarathon. Belinchón-deMiguel et al. (2024) documented concurrent thermographic and physiological parameters across a 4-day competition. However, this preliminary study involved only three athletes, limiting statistical power and generalizability of findings. While their work establishes foundational insights into thermal regulation during extreme endurance events, the small cohort underscores the need for expanded research with larger participant groups to validate patterns and optimize monitoring protocols. To address this gap, this study aimed to (1) longitudinally assess total body and thigh TSk dynamics and (2) evaluate their temporal correlations with running distance and RPE before, 2h, 4h, and after a 6-hour. A secondary aim was to explore whether real-time temperature monitoring could inform pacing strategies to optimize performance and minimize the risk of race abandonment. We hypothesized that increasing thermal strain (elevated body and thigh TSk) and higher RPE responses would correlate with running distance.

## **2. Methods**

### **2.1. Experimental approach**

This study was conducted in collaboration with the commanders of the Military Base of Paratroopers "Príncipe" (BRIPAC), located in Madrid, Spain, a specialized unit renowned for high-intensity tactical training. Following institutional approval, commanders publicized details of a 6-hour endurance running event designed for scientific investigation. Volunteers were invited to attend a pre-event briefing 24 hours prior to the trial to review protocols and eligibility criteria. During the pre-event briefing, participants were informed of the study's aims, procedures, potential risks, and benefits. Written and oral instructions were provided, emphasizing the following pre-trial requirements: (a) Refrain from high-intensity exercise, cycling, or running to the event site, (b) avoid alcohol, tobacco, caffeine, and energy drinks for 24 hours prior, (c) maintain a minimum of 7 hours of sleep nightly in the preceding week and; (d) avoid from shaving, massages, or topical creams/ointments on measurement areas. After the consent the participants were assigned a unique identification bib number for anonymized data tracking.

### **2.2. Participants**

Inclusion criteria required participants to be: (a) male; (b) aged 18–50 years; (c) free of musculoskeletal injuries or illnesses in the preceding three months (medically cleared for high-intensity activity); and (d) maintaining a minimum training load of 15 hours weekly, including running sessions  $\geq 2$  hours. Exclusion criteria were: (a) acute musculoskeletal injuries impairing training capacity within the prior three months; (b) participation in competitive events or maximal-effort activities within seven days pre-trial; (c) training within 24 hours pre-event; or (d) wish to withdraw from the study or not participate in all stages. A priori power analysis (*GPower* 3.1.7; Franz Faul, Universität Kiel, Germany) for a repeated-measures ANOVA (3 groups, 8 measurements) indicated a required sample of 39 participants (effect size  $f = 0.5$ ,  $\alpha = 0.05$ , power = 0.95). Therefore, thirty-nine male elite soldiers (training volume:  $5.8 \pm 4.5$  hours/week;  $39.2 \pm 20.6$  km/week) were stratified post-hoc into three performance-based groups following the 6-hour endurance event: (a) Ultramarathon Group:  $>44$  km ( $n = 12$ ); (b) Marathon Group: 40–44 km ( $n = 15$ ) and; (c) Sub-Marathon Group:  $<40$  km ( $n = 12$ ). Baseline anthropometric and training metrics (Table 1) showed no intergroup differences ( $p > 0.05$ ), confirming homogeneity at baseline.

**Table 1.** Characteristics of the participants of three groups.

	Ultramarathon (n=12)	Marathon (n=15)	Sub-marathon (n=12)
<b>Age (years)</b>	27.6 ± 6.4	28.4 ± 7.8	26.5 ± 4.0
<b>Height (m)</b>	1.8 ± 0.1	1.8 ± 0.1	1.8 ± 0.0
<b>Body Mass (kg)</b>	74.8 ± 10.2	77.2 ± 5.7	78.6 ± 10.3
<b>BMI (kg/m<sup>2</sup>)</b>	24.5 ± 3.2	24.1 ± 1.7	25.5 ± 3.1
<b>Experience (years)</b>	16.2 ± 7.0	17.5 ± 8.9	12.1 ± 7.1

BMI: body mass index.

### **2.3. Data Collection Protocol**

A battery of assessments was conducted at four time points: (a) PRE: 30 minutes before the run; (b) POST<sub>2h</sub> and POST<sub>4h</sub>: At 2-hour and 4-hour intervals during the run; (c) POST<sub>6h</sub>: Immediately post-run. We measured: (a) questionnaire: training history, injury profile, and demographics collected pre-event; (b) anthropometrics: height (measured once, pre-event) and body mass (SECA 813 scales, Deutschland, ±0.1 kg) recorded at all time points; (c) Thermography: Infrared images captured for total body and thigh regions in a temperature-controlled room (22°C, 50% humidity); (d) RPE assessed using the Borg CR-10 scale; (e) distance covered (km): tracked via video. This research protocol received approval from the Ethics Committee of the Federal University of Juiz de Fora (Protocol No. 3.085.114) and adhered to the Declaration of Helsinki.

### **2.4. Measurements**

#### **2.4.1 Anthropometrics**

On the day before the event, to calculate the body mass index (BMI), the height was measured with a stadiometer (SECA 213®, Deutschland, ±0.1 cm) following the ISAK guidelines by an accredited level 3 anthropometrist, and the body mass was recorded in a Portable 3D Force Plate (Kistler®, Type 9286, Switzerland).

#### **2.4.2 Body Temperature**

TSk was measured using a FLIR T530 thermographic camera (FLIR® Systems, Sweden) with the following specifications: measurement range (-20°C to +120°C), ±2% accuracy, thermal sensitivity ≤0.05°C, spectral band (7.5–14 μm), 60 Hz refresh rate, autofocus, and 320 × 240 pixels resolution. During the first day thermogram session, participants underwent a 10-minute acclimation period to room temperature, during which baseline



data were recorded. Subsequent thermograms omitted this acclimation phase in accordance with the study protocol. Prior to imaging, participants removed their shirts and adjusted their shorts to expose the gluteal region, enabling standardized capture of four anatomical views. For this study, anterior superior (AS) and posterior superior (PS) thermograms were used to estimate Body Surface Temperature (BST), posterior inferior (PI) was used to measure thigh temperature, and anterior inferior (AI) was utilized for both thigh temperature and BST assessment. Participants stayed 3 meters from the camera, which was aligned perpendicularly to either the trunk (for AS/PS views) or knees (for AI/PI views).

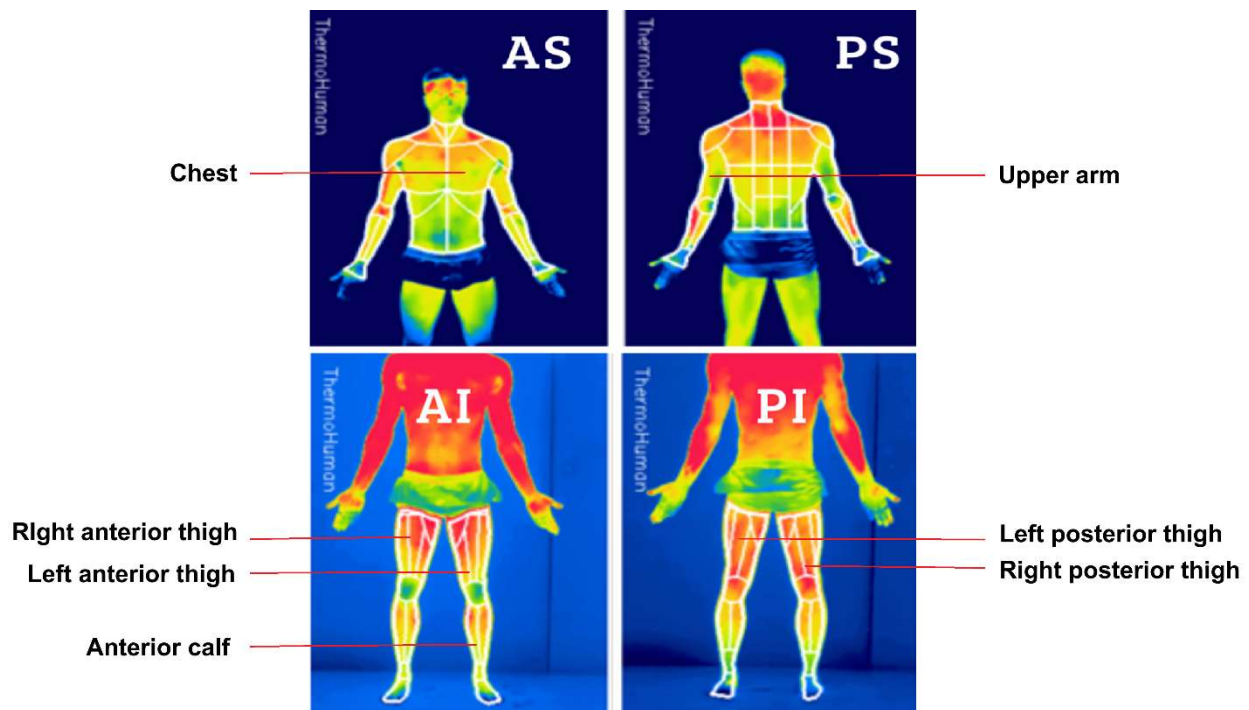
All thermograms were analyzed using Thermohuman® software (Madrid, Spain), which automatically generated regions of interest (ROIs) on each body side. To minimize methodological errors, the feet, wrists, neck, and buttocks were excluded due to potential confounding factors (e.g., clothing, footwear, or hair). For data reduction, original ROIs were consolidated into integrated TSk values for the anterior and posterior thighs (Figure 1) using the formula:

$$[(XTSk_1 \times n_1) + (XTSk_2 \times n_2) + \dots + (XTSk_n \times n_n)] / [n_1 + n_2 + \dots + n_n]$$

XTSk = mean skin temperature of each original ROI; n = number of pixels in each ROI; the formula calculates the integrated mean skin temperature (TSk) weighted by the number of pixels across the selected regions.

BST (Figure 1) was calculated using the formula derived from Ramanathan (1964):

$$BST = 0.3 \times [chest] + 0.3 \times [upper\ arm] + 0.2 \times [thigh] + 0.2 \times [calf].$$



**Figure 1.** Example of thermographic images analyzed. AS – Anterior superior, PI – posterior inferior, AI – Anterior inferior, PI – posterior inferior. ROI occupied for BST estimative: Chest, Anterior right thigh, Anterior calf, and Posterior upper arm.

#### 2.4.3 Rating of Perceived Exertion

To register the subjective perception of the participants in terms of exertion, the rate was used 3 different times of the test. The 10-point (0-10) Perceived Exertion scale proposed by Foster et al. (2021) was used to record each participant's perception of exertion at the end of each series of the event (POST<sub>2h</sub>, POST<sub>4h</sub> and POST<sub>6h</sub>).

#### 2.4.4 Temperature and Humidity

The temperature of the data collection area and environmental conditions were recorded using two weather stations (Auriol®, model H13726A, Spain) with a resolution of 0,1°C and 1% relative humidity. Environmental conditions at the different measurement moments are displayed in Table 2.

**Table 2.** Environmental conditions during the data collection

	PRE	POST <sub>2h</sub>	POST <sub>4h</sub>	POST <sub>6h</sub>
Room Temperature (°C)	19.6 ± 0.3	19.6 ± 0.6	22.0 ± 0.8	22.7 ± 0.6
Air Humidity (%)	54.7 ± 0.6	54.3 ± 0.6	50.3 ± 2.3	46.3 ± 2.9
Outside Temperature (°C)	17.0 ± 1.7	18.5 ± 0.7	23.3 ± 1.2	23.3 ± 0.6

#### *2.4.5 Performance – Distance covered*

Long-term endurance running was recorded using a Sony® DCR-SR37 digital video camera (Japan) to track lap durations and calculate total distance covered by each athlete throughout the testing period. The race started at 8:15 am on a standardized 400-meter Olympic official track. Participants began the race individually at 2-minute intervals, following a randomized bib order assigned the day prior to streamline intermediate data collection. A pre-edited audio recording, broadcast via a sound system, facilitated real-time individualized timekeeping. This recording alerted athletes (via bib number) to: (a) start the race; (b) Refrain from eating 15 minutes prior to intermediate data collection; (c) report to the research station for intermediate assessments; (d) return to the track after the 15-minute interval, and (e) conclude the event.

Athletes self-selected their pacing strategy and wore personal running attire (shorts and short-sleeved shirts). Each participant had a dedicated station along the main immediately, marked by their bib number, containing ad libitum access to food and water (chocolate/cereal bar, banana, water). Bathroom breaks were permitted at any time but were typically timed to coincide with the 15-minute intervals to minimize disruptions.

#### **2.5. Statistical analyses**

Statistical analyses were conducted using SPSS® (Version 21; IBM, USA). Descriptive statistics for all variables were calculated and presented as mean ± standard deviation (SD) to summarize central tendency and dispersion. Data normality was first assessed via the Shapiro-Wilk test. To identify differences between the groups, a one-way ANOVA with Tukey's post-hoc test for pairwise comparisons was performed. Effect sizes for ANOVA were calculated using partial eta-squared ( $\eta^2$ ), and a significance of  $p \leq 0.05$  was applied to all analyses.

### 3. Results

A significant main effect of group was observed for total distance ( $F_{2,38} = 34.572$ ,  $p < 0.001$ ,  $\eta^2 = 0.729$ ). The Ultra group covered the highest distance ( $p < 0.001$  for all comparison), followed by the Marathon and the Sub-Marathon. For partial distance after applying sphericity correction (Greenhouse-Geisser), a significant Group  $\times$  Time interaction emerged ( $F_{2,38} = 2.582$ ,  $p = 0.044$ ,  $\eta^2 = 0.125$ ). Across all time intervals (PRE, POST<sub>2h</sub>, POST<sub>4h</sub>, POST<sub>6h</sub>). The Ultra group maintained higher distances compared to both Marathon ( $p \leq 0.044$ ) and Sub-Marathon ( $p < 0.001$ ). The Marathon group outperformed the Sub-Marathon group ( $p \leq 0.041$ ). All groups exhibited reduced distances in the POST<sub>6h</sub> window compared to earlier intervals (POST<sub>2h</sub>: and POST<sub>4h</sub>:  $p < 0.001$  for all comparison), except for the Sub-Marathon group between POST<sub>2h</sub> and POST<sub>4h</sub> ( $p = 0.055$ ). A significant main effect of time was observed for BST ( $F_{2,38} = 7.134$ ,  $p = 0.001$ ,  $\eta^2 = 0.386$ ). Post-hoc comparisons indicated elevated BST at POST<sub>6h</sub> compared to PRE (mean difference:  $+1.9^\circ\text{C}$ , 95% CI [0.1, 3.7],  $p = 0.037$ ), POST<sub>2h</sub> (mean difference:  $+2.3^\circ\text{C}$ , 95% CI [0.7, 4.0],  $p = 0.002$ ). For RPE, we observed an isolated effect of moment of measurement ( $F_{2,35} = 30.794$ ,  $p \leq 0.001$ ,  $\eta^2 = 0.638$ ), where POST<sub>6h</sub> showed a high PSE vs. POST<sub>4h</sub> ( $p \leq 0.001$ ) and 2h ( $p = 0.009$ ), and POST<sub>4h</sub> showed a high PSE vs. POST<sub>2h</sub> ( $p \leq 0.001$ ). Detailed results for distance, BST and PSE across time intervals are presented in Table 3.

**Table 3.** Results of BST between the groups at the PRE, POST<sub>2h</sub>, POST<sub>4h</sub>, POST<sub>6h</sub> moments of measurement.

<b>Distance (km)</b>				
<b>Groups</b>	<b>POST<sub>2h</sub></b>	<b>POST<sub>4h</sub></b>	<b>POST<sub>6h</sub></b>	<b>Total</b>
Ultra	21.5±3.4 <sup>a*</sup>	15.7±3.7 <sup>b*</sup>	12.3±2.4 <sup>*</sup>	49.4±7.5 <sup>*</sup>
Marathon	18.1±2.4 <sup>a#</sup>	13.2±1.9 <sup>b#</sup>	10.2±1.7 <sup>b#</sup>	41.5±1.3 <sup>#</sup>
Sub-marathon	13.6±3.6	10.7±1.6 <sup>b</sup>	8.5±0.7	32.7±4.5
<b>Body skin temperature (°C)</b>				
<b>Groups</b>	<b>PRE <sup>c</sup></b>	<b>POST<sub>2h</sub> <sup>c</sup></b>	<b>POST<sub>4h</sub></b>	<b>POST<sub>6h</sub></b>
Ultra	29.9±3.0	28.3±5.5	27.8±9.6	31.9±0.6
Marathon	30.6±0.1	29.6±1.3	30.3±2.7	30.9±2.5
Sub-marathon	28.3±5.9	29.5±3.4	30.6±3.2	31.6±1.0
<b>Rating of perceived exertion (a.u.)</b>				
<b>Groups</b>		<b>POST<sub>2h</sub> <sup>d</sup></b>	<b>POST<sub>4h</sub> <sup>c</sup></b>	<b>POST<sub>6h</sub></b>
Ultra		4.5±1.3	6.4±1.4	7.4±0.8
Marathon		3.8±1.4	5.5±1.5	6.1±2.0
Sub-marathon		3.4±1.0	4.3±1.4	5.0±1.5

<sup>a</sup>  $p \leq 0.001$  this moment of measurement vs. POST<sub>4h</sub> and POST<sub>6h</sub>. <sup>b</sup>  $p \leq 0.001$  this moment of measurement vs. POST<sub>6h</sub>. <sup>c</sup>  $p \leq 0.037$  this moment of measurement vs. POST<sub>6h</sub>. <sup>d</sup>  $p \leq 0.001$  this moment of measurement vs. POST<sub>4h</sub> and POST<sub>6h</sub>. \*  $p \leq 0.001$  vs. Marathon and Sub-marathon. #  $p \leq 0.001$  Sub-marathon.

A significant main effect of time was observed for anterior thigh temperature ( $F_{2,38} = 18.108$ ,  $p < 0.001$ ,  $\eta^2 = 0.809$ ). Post-hoc comparisons revealed lower temperatures at Pre-exercise and POST<sub>2h</sub> compared to POST<sub>4h</sub> and POST<sub>6h</sub> ( $p < 0.001$  for all comparison). Additionally, the right thigh exhibited a significant decline at POST<sub>6h</sub> compared to baseline ( $p = 0.038$ ). Similarly, posterior thigh temperature showed a significant main effect of time ( $F_{2,38} = 27.272$ ,  $p < 0.001$ ,  $\eta^2 = 0.864$ ). Temperatures at Pre-exercise and POST<sub>2h</sub> were significantly lower than those at POST<sub>4h</sub> and POST<sub>6h</sub> ( $p < 0.001$  for all comparison). Finally, at POST<sub>6h</sub>, a lateral asymmetry emerged, with the right leg cooler than the left (right:  $p = 0.034$ ; left:  $p = 0.036$ ). Table 4 summarizes anterior and posterior thigh temperature measurements across the three groups before, during and after the race.

**Table 4.** TSk temperatures measured at PRE, POST<sub>2h</sub>, POST<sub>4h</sub>, POST<sub>6h</sub> of the trial, for the anterior and posterior thigh ROI.

Anterior thigh temperature (°C)								
Side	PRE		POST <sub>2h</sub>		POST <sub>4h</sub>		POST <sub>6h</sub>	
	Right	Left	Right	Left	Right	Left	Right	Left
Ultra	30.4±0.7 <sup>a</sup>	30.3±0.7 <sup>a</sup>	29.7±0.9 <sup>a</sup>	29.7±0.9 <sup>a</sup>	31.6±0.6 <sup>b</sup>	31.5±0.6	32.1±0.6	32.0±0.6
Marathon	30.3±0.7 <sup>a</sup>	30.3±0.8 <sup>a</sup>	29.6±1.4 <sup>a</sup>	29.6±1.4 <sup>a</sup>	30.9±1.2 <sup>b</sup>	30.8±1.1	31.3±1.0	31.2±1.0
Sub-marathon	30.0±0.7	30.0±0.8 <sup>a</sup>	29.7±2.0 <sup>a</sup>	29.7±1.9 <sup>a</sup>	31.1±0.9 <sup>b</sup>	31.1±1.0	31.2±0.9	31.2±1.0
Posterior thigh temperature (°C)								
Ultra	29.8±1.1 <sup>a</sup>	29.9±1.0 <sup>a</sup>	29.9±1.1 <sup>a</sup>	30.1±1.0 <sup>a</sup>	31.6±0.8 <sup>c</sup>	31.6±0.7 <sup>d</sup>	32.1±0.7	32.1±0.6
Marathon	29.9±0.6 <sup>a</sup>	29.9±0.6 <sup>a</sup>	29.8±1.2 <sup>a</sup>	29.7±1.2 <sup>a</sup>	31.0±1.3 <sup>c</sup>	31.1±1.4 <sup>d</sup>	31.3±1.1	31.4±1.1
Sub-marathon	29.4±0.8 <sup>a</sup>	29.5±0.8 <sup>a</sup>	30.0±1.7 <sup>a</sup>	30.0±1.6 <sup>a</sup>	31.1±1.0 <sup>c</sup>	31.1±1.0 <sup>d</sup>	31.3±1.1	31.3±1.0

ROI – region of interest. <sup>a</sup> p≤0.001 this moment of measurement vs. POST<sub>4h</sub> and POST<sub>6h</sub>.

<sup>b</sup> p=0.038 this moment of measurement vs. right anterior thigh at POST<sub>6h</sub>. <sup>c</sup> p=0.034 this moment of measurement vs. right posterior thigh at POST<sub>6h</sub>. <sup>d</sup> p=0.036 this moment of measurement vs. left posterior thigh POST<sub>6h</sub>.

Table 5 showed the significative difference between the total distance and RPE, body and thigh temperature. Among all measured correlated, we found a significative and positive correlation between total distance and the temperature of the right and left thigh at POST<sub>6h</sub> (p≤0.036 for all comparison) and RPE at POST<sub>4h</sub> and POST<sub>6h</sub> (p≤0.008 for all comparison). At the last, we found an inverse correlation between the BST at POST<sub>4h</sub> and the total distance (p≤0.001). There was not significative correlation between the calf temperature and total distance (p≥0.182).

**Table 5.** Significative correlations between temperature, rating of perceived exertion and performed distance.

	BST 4h	ART POST <sub>6h</sub>	ALT POST <sub>6h</sub>	PRT POST <sub>6h</sub>	PLTPOST <sub>6h</sub>	RPE POST <sub>4h</sub>	RPE POST <sub>6h</sub>
Distance	r=-0.551; p≤0.001	r=0.365; p=0.022	r=0.373; p=0.019	r=0.344; p=0.032	r=0.325; p=0.043	r=0.419; p=0.008	r=0.48; p=0.002

ART – anterior right thigh; ALT – anterior left thigh; PRT – posterior right thigh; PLT – posterior left thigh; RPE – rating of perceived exertion.

#### **4. Discussion**

To advance our understanding of thermoregulatory adaptations in endurance running, prior research has examined fluctuations in TSk before, during, and after running (Gutiérrez-Vargas et al., 2017; Priego-Quesada et al., 2020). However, significant gaps persist in studies of prolonged events such as 6-hour runs, particularly regarding the dynamics of BST and TSk over extended durations. Current evidence remains limited, with only one small-scale case study (n=3 athletes) documenting thermographic responses during ultramarathon events (Belinchón-deMiguel et al., 2024). These limitations underscore the need for more robust investigations to clarify thermal behavior and inform practical strategies for athletes. In this context, we aimed to correlate the total distance covered with BST and thigh skin (anterior/posterior ROI), and RPE before and intervals during, and after a 6-hour run. Main findings revealed that total distance achieved was positively correlated with a high temperature at 6 hours and RPE at 4 and 6 hours, while inversely correlated with BST at 4 hours. Significant differences emerged in BST between baseline/2-hour measurements and later timepoints (4/6 hours). Similarly, anterior and posterior thigh temperatures diverged at 4 versus 6 hours, except in the left anterior thigh. Together, these results offer actionable insights for coaches and athletes helping to monitor thigh temperature trends and RPE during prolonged runs could aid in refining hydration protocols, pacing strategies, and effort distribution to optimize performance.

To better understand thermoregulatory adaptations during running, some studies have analyzed body and skin temperature before and after running, but not during the activity. However, there is still no information on these adaptations in races lasting many hours, such as a 6-hour run. Additionally, the behavior of body and skin temperature during long-term endurance running remains unknown.

To our knowledge, this is the first study to correlate performed distance, temperature (body and thigh) and rating of perceived exertion (RPE) before, during and after a long-term endurance running (6-hours). The main results indicated that the total distance performed was directly correlated with thigh temperature at 6h and RPE at 4 and 6h, inversely total distance was correlated with BST at 4h. Therefore, there were differences between the temperatures at Pre and 2h versus 4h and 6h for the BST. Similar results were observed

to the anterior and posterior thigh, however, we observed difference for these ROI between 4h versus 6h, except to the anterior left thigh.

The mean performed distance by the ULTRA group was  $49.4 \pm 7.5$  km; the MARATHON group covered  $41.5 \pm 1.3$  km; and the SUB-MARATHON group covered  $32.7 \pm 4.5$  km. These distances were shorter than those reported in other studies that also conducted 6-hour races. Matta et al. (2019) carried out two 6-hour races within a 30-day interval, with only 10 of the 16 participants from the first race taking part in the second. In this second race, the authors controlled the participants' initial speed during the first 36 minutes of the event (10% of the total time). The distance covered by participants during the first race was  $58.9 \pm 9.4$  km, and in the second race, it remained the same.

Kerhervé et al. (2017) evaluated eight trained ultramarathon runners in a 6-hour treadmill run. The protocol consisted of three 100-minute self-paced modules and four 15-minute modules in which there were variations in pace and treadmill incline. These participants ran a total distance of  $58.3 \pm 10.5$  km. Wollseiffen et al (2016) identified the effect of 6h of running on the progression of cognitive, performance and mood. The course was 1173 meters flat loop and the eleven ultramarathoners ran  $60.02 \pm 5.31$  km.

For running to be efficient, the optimal use of the lower limb joints' mass-spring mechanism is necessary to propel the body forward (PANDAY et al., 2022). Therefore, the thigh muscles are very important for the functioning of this mechanism. As a result, in this study, we evaluated the thighs' skin temperature. The result for thigh temperature showed a significant main effect of time for both the anterior and posterior regions, with lower temperatures observed at Pre-exercise and POST2h compared to POST4h and POST6h. These results are consistent with findings from other research that also assessed skin temperature following races longer than 10 km. The result for BST (body skin temperature) showed a statistical significance for the moment of measurement, where the means observed at 6 hours differed significantly from the means measured at Pre and 2 hours.

These findings have also been reported in other studies. Byrne et al. (2022) continuously measured core body temperature using a telemetric temperature-sensing capsule in twenty-three sub-elite recreational runners throughout an 89-km Ultramarathon Road Race. They observed a mean final core temperature of  $38.6^{\circ}\text{C}$  ( $\pm 0.6^{\circ}\text{C}$ ), with runners spending 72% of the race time within the core temperature range of  $38.0$  to  $38.9^{\circ}\text{C}$ . Fernandes et al. (2018) reported a decrease in skin temperature (TSk) immediately after treadmill running at increasing intensities up to 85% of maximum heart rate, followed by rewarming during recovery. Similarly, Oliveira et al. (2018) found a decrease in TSk in



distal body regions during incremental effort on an upper limb ergometer, with reductions observed in the lower limbs and trunk during exercise, followed by recovery-phase rewarming. Korman et al. (2024) analyzed four groups - futsal players, endurance runners, sprinters, and recreational runners - and found that changes in TSk were influenced by total skeletal muscle mass and lower limb fat percentage. Their findings also indicated a significant decrease in TSk during exercise, followed by rapid rewarming during recovery. Racinais et al (2021) evaluated 83 marathon and racewalking athletes who participated in the Doha 2019 IAAF World Athletics Championships. One of the main findings of the study was that athletes who did not finish the race had a higher pre-race skin temperature (TSk;  $33.8^{\circ}\text{C} \pm 0.9^{\circ}\text{C}$  vs  $32.6^{\circ}\text{C} \pm 1.4^{\circ}\text{C}$ ), while among finishers a lower pre-race TSk was moderately associated with faster race completion ( $r = 0.32$ ). Quesada et al (2022) assessed the effect of a 10 km run at moderate intensity on baseline skin temperature and thermal response after a cold stress test during that 24 h period (14 participants in the experimental group). The main results were that the experimental group presented higher increases with an effect that was maintained 24 h after undertaking exercise (10 km running) in the anterior and posterior leg, and posterior knee ROIs. In another study, Quesada et al (2020) not found differences in basal skin temperatures between the 4 days of testing performed with 16 recreational marathon runners.

Andrade et al. (2022) conducted an experiment in an environmental chamber, where participants ran 10 km on a treadmill in a hot environment. While skin temperature did not show significant variation, core temperature (measured via rectal thermometer) increased by an average of  $2.7^{\circ}\text{C}$  over the course of the trial. Naito et al. (2024) evaluated seven highly trained athletes who performed cognitive tasks to induce mental fatigue while undergoing warm water immersion at  $40^{\circ}\text{C}$  (HYP) or passive heat exposure in a climatic chamber at  $35^{\circ}\text{C}$  with 60% relative humidity (SKIN) for 45 minutes before exercise. Following these conditions, participants completed a running test at 80% of maximal oxygen consumption until voluntary exhaustion in the same chamber as the SKIN condition. The time to exhaustion was significantly shorter in the HYP test ( $538 \pm 200$  s) compared to the SKIN test ( $757 \pm 324$  s).

During exercise, one of the keys determinants of pacing regulation is perceived effort. Athletes will adapt their pace based on their perception of effort, which they therefore have to compare, in a conscious manner, to an expected effort (template) based on their former experiences (Schallig et al, 2017). In our results, the perception of effort (RPE) at 4h and 6h showed a significant increase when compared to pre-race. Similarly, Matta et al (2019)

met the increased consistently throughout the 6h race in the RPE. Another studies have shown that pacing is mediated by RPE (Koning et al., 2011; Koning e Hettinga, 2018), displaying linear increases throughout a task, as a function of the exercise time remaining. In your study, Hasegawa et al (2025) met a main effect of condition and distance for RPE. Regardless of sex, RPE was higher in hypoxia than normoxia, with progressive increase from the beginning to the end of the trial in both conditions. Kerhervé et al (2017) evaluated 8 participants within a 6 h running exercise on a treadmill (6TR) and the results were similar to other studies showed a positive pacing (decreasing speed) and increased perceived exertion over the 6TR.

## **5. Limitations**

Although the military volunteers were highly trained and regularly practiced running, they did not specifically train for ultramarathons. Conducting a similar study with athletes who specialize in ultramarathon training would be valuable. Another avenue for future research is to investigate races with different durations and distances beyond 6 hours, such as 50 km, 100 km, 12-hour, or 24-hour events. These studies could be conducted in official competitions held on closed-loop courses, whether on official athletics tracks, as in this study, or on other types of terrain and loop distances.

Another limitation of this study was that athletes ran exclusively in a clockwise direction throughout the 6-hour race. This decision was made to accommodate the positioning of the race recording system. In races with short loops, such as the 400 m track used in this study, it would be beneficial to alternate the running direction every 1 or 2 hours, provided that accurate lap time monitoring could be maintained in both directions.

## **6. Practical Applications**

The main finding of this study was the observed correlation between running speed, RPE, and body and thigh skin temperature. As time progressed, all groups exhibited a decrease in speed, indicating a positive pacing strategy, along with increases in both RPE and skin temperature, supporting the initial hypothesis. These results suggest that monitoring body temperature and perceived exertion during training and long-distance events may help athletes and coaches maintain target pacing throughout prolonged efforts in marathon and ultramarathon races.

## 7. Conclusion

This study aimed to (1) longitudinally assess total body and thigh skin temperature (TSk) dynamics and (2) evaluate their temporal correlations with running distance and rating of perceived exertion (RPE) before, 2h, 4h, and after a 6-hour endurance run. A secondary objective was to explore whether real-time temperature monitoring could inform pacing strategies to optimize performance and minimize the risk of race abandonment.

The findings confirmed our hypothesis: participants showed a progressive increase in TSk and RPE over the running, while running speed decreased (a positive pacing strategy). Notably, greater running distances were positively correlated with higher thigh skin temperatures and RPE at 4h and 6h, and inversely correlated with body surface temperature (BST) at 4h.

These results highlight the relevance of monitoring thermal and perceptual responses during prolonged exercise. Tracking TSk and RPE in real-time may serve as a valuable strategy to manage pacing and hydration, reduce thermal strain, and ultimately improve endurance performance. Coaches and athletes could benefit from incorporating these markers into training and competition planning.

Future studies should build on these findings by investigating longer races and specialized ultramarathon populations to further clarify how thermoregulatory responses impact performance in extreme endurance events.

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## ARTICLE 2 – Analysis of cardiovascular, metabolic, and perceptual responses before, during, and after a long-duration endurance running.

Este artigo será submetido ao *Journal of Sports Science* (Qualis A1).

### Abstract

**Aims:** to analyze and compare cardiovascular, metabolic, and perceptual responses in trained male runners before, during, and after a six-hour continuous running, with emphasis on performance-based differences and recovery dynamics up to 48 hours post-exercise.

**Methods:** thirty-nine elite male soldiers (age:  $31.4 \pm 5.7$  years) participated in a 6-hour continuous run on a 400-meter track under ambient temperature ( $28.5 \pm 3.2^{\circ}\text{C}$ ). Participants were retrospectively categorized into three groups based on total distance covered: sub-marathoners ( $<40$  km), marathoners (40–44 km), and ultramarathoners ( $>44$  km). Physiological variables (heart rate, blood pressure, body mass), metabolic markers (urinalysis), and perceptual responses (pain, thirst, thermal sensation, skin wetness, thermal comfort, and exertion) were assessed at six time points: before (PRE), during (POST2h, POST4h, POST6h), and after the run (POST24h, POST48h).

**Results:** Ultrarunners showed greater reductions in body mass, higher heart rate responses, and increased discomfort across multiple perceptual domains. Several variables remained significantly altered even 48 hours post-exercise, particularly in the ultramarathon group. Repeated-measures analysis revealed significant time effects ( $p < 0.001$ ) for most variables, and interaction effects indicating performance-level differences in recovery profiles.

**Conclusion:** Greater running volume was associated with more intense and prolonged physiological and perceptual strain, highlighting the need for individualized recovery strategies following ultra-endurance exertion. The integration of cardiovascular, metabolic, and perceptual markers provides a comprehensive perspective on fatigue and recovery, with practical implications for endurance training and performance management.

**Keywords:** endurance running; cardiovascular responses; thermal perception; ultra-endurance; urinary biomarkers.

## 1. Introduction

Ultramarathons are defined as races longer than a marathon and have become increasingly popular, with a rise in the number of events and participants. This phenomenon has spurred growing scientific interest in the physiological and perceptual effects imposed by endurance exercise (Cejka et al., 2014; Spittler & Oberle, 2019). Many of these competitions take place under extreme environmental conditions, with temperatures frequently exceeding 30°C and relative humidity above 70% (Bouscaren et al., 2019). In such contexts, environmental heat combined with the metabolic heat generated by exercise can impair thermoregulatory mechanisms, particularly in athletes lacking adequate acclimatization or hydration strategies (Ebi et al., 2021).

Ultramarathons represent complex physiological challenges, requiring deeper scientific understanding, particularly when performed by recreational athletes exposed to severe thermal stress conditions. They impose high levels of physiological strain, demanding both acute and chronic adaptations of the cardiovascular, metabolic, and thermoregulatory systems. During prolonged efforts such as marathons and ultramarathons, a sustained elevation in heart rate, alterations in blood pressure, and significant loss of body fluids through sweating are commonly observed (Kenefick et al., 2007).

Long-duration endurance running is often performed under widely varying environmental conditions (heat, humidity, direct solar radiation, wind, and rain) which interact with exercise intensity and exposure time, directly influencing thermal balance. In these scenarios, the accumulation of internal heat without adequate dissipation may impair athletic performance and increase the risk of complications such as severe dehydration and hyperthermia (Roberts et al., 2023). The combination of thermal stress, cardiovascular strain, and fluid depletion compromises performance and elevates the risk of physiological collapse, making the monitoring of these variables essential in prolonged exercise contexts.

In addition to physiological markers, perceptual responses have been widely used as valid and sensitive tools to monitor internal load during prolonged exercise. Scales assessing thermal sensation, thirst, pain, recovery, and exertion provide direct access to the athlete's experience, offering relevant insights into tolerance to physiological and environmental stress. This is particularly important given that, during continuous exercise, pacing is influenced by the integration of top-down (cognitive) and bottom-up



(physiological) processing factors (Borg, 1982; Costa et al., 2019; Kenttä & Hassmén, 1998).

Similarly, in field settings such as road races or military events, these measures are particularly useful due to their practical applicability, low cost, and ease of collection at various points throughout the event (Capitán-Jiménez & Aragón-Vargas, 2018). When interpreted alongside physiological data, perceptual variables contribute to a more comprehensive understanding of fatigue, supporting the adjustment of strategies during competition and recovery after exertion.

Although previous studies have documented hemodynamic and perceptual changes during running, most are based on short-duration protocols or conducted in controlled environments (Pekola-Kiviniemi et al., 2025; Racinais et al., 2021). There is a lack of field-based evidence that replicates the complexity of the demands faced by athletes during six-hour or longer events, with repeated measurements throughout the effort and into the recovery period.

Moreover, few studies have tracked the progression of physiological and perceptual responses after exertion, especially when comparing different runner profiles. It remains unclear whether variables such as body mass, pain, thirst, and thermal comfort return to baseline levels within the first 24 hours or remain altered for up to 48 hours, and whether these dynamics vary according to the runners' performance level (Belli et al., 2018; Tillman et al., 2015; Valentino et al., 2016).

Understanding these differences has important practical implications for planning the return to training, injury prevention, and the prescription of individualized recovery strategies. For example, interventions targeting hydration or training load reduction can be adjusted according to the athlete's profile and post-race response.

Based on this, we hypothesized that ultra-endurance runners, due to prolonged exposure to physiological stress, would exhibit more intense and prolonged physiological and perceptual responses compared to the other groups. We expected to observe greater dehydration, more pronounced changes in perceptual and physiological markers, and a slower recovery in the ultramarathon group.

This study adopted a longitudinal field-based approach to analyze cardiovascular (heart rate, blood pressure, body mass), metabolic (urine biomarkers), and perceptual (pain, thermal sensation, thirst, comfort) responses in three groups of runners before, during (every 2 hours), and after (24h and 48h) a 6-hour running event. These data may

contribute to improved understanding of recovery dynamics and inform targeted strategies for endurance athletes.

Given this context, the aim of this study was to analyze cardiovascular, metabolic, and perceptual responses in runners before, during, and after a 6-hour running event.

## **2. Methods**

### **2.1. Experimental Design**

This study was conducted in collaboration with the commanders of the "Príncipe" Paratrooper Military Base (BRIPAC), located in Madrid, Spain, a specialized unit recognized for its high-intensity training. After institutional approval, a 6-hour endurance running event was formally announced and structured for scientific purposes.

All eligible volunteers were invited to a pre-event briefing held 24 hours prior to the trial. During this session, participants received oral and written information regarding the study's objectives, procedures, potential risks, and benefits. Specific pre-trial guidelines were emphasized to ensure standardization, including: (a) abstaining from high-intensity exercise and from running or cycling to the event site; (b) avoiding alcohol, tobacco, caffeine, and energy drinks in the 24 hours preceding the trial; (c) maintaining at least 7 hours of sleep per night during the week prior; and (d) avoiding shaving, massages, or the application of topical creams or ointments to areas designated for physiological measurement.

After providing informed consent, participants were assigned unique bib numbers to ensure anonymized data tracking throughout the study protocol.

### **2.2. Participants**

Inclusion criteria required participants to be: (a) male; (b) aged between 18 and 50 years; (c) free of musculoskeletal injuries or illnesses in the preceding three months, and medically cleared for high-intensity activity; and (d) maintaining a minimum training load of 15 hours per week, including weekly running sessions of at least 2 hours. Exclusion criteria included: (a) acute musculoskeletal injuries impairing training capacity within the prior three months; (b) participation in competitive events or maximal-effort activities within seven days prior to the trial; (c) engaging in training within 24 hours pre-event; or (d) unwillingness to complete all stages of the study.

An a priori power analysis (G\*Power 3.1.7; Franz Faul, Universität Kiel, Germany) for a repeated-measures ANOVA (3 groups × 8 time points) indicated a required sample

size of 39 participants (effect size  $f = 0.5$ ,  $\alpha = 0.05$ , power = 0.95). Accordingly, thirty-nine male military personnel (training volume:  $5.8 \pm 4.5$  hours/week;  $39.2 \pm 20.6$  km/week) were enrolled and stratified post hoc into three performance-based groups according to total distance covered in the 6-hour endurance running event: (a) Ultramarathon:  $>44$  km ( $n = 12$ ); (b) Marathon:  $40\text{--}44$  km ( $n = 15$ ); and (c) Sub-Marathon:  $<40$  km ( $n = 12$ ). Baseline anthropometric and training metrics (Table 1) showed no intergroup differences ( $p > 0.05$ ), confirming homogeneity at baseline.

Table 1. Characteristics of the participants of three groups.

	Ultramarathon (n=12)	Marathon (n=15)	Sub-marathon (n=12)
<b>Age (years)</b>	$27.6 \pm 6.4$	$28.4 \pm 7.8$	$26.5 \pm 4.0$
<b>Height (m)</b>	$1.8 \pm 0.1$	$1.8 \pm 0.1$	$1.8 \pm 0.0$
<b>Body Mass (kg)</b>	$74.8 \pm 10.2$	$77.2 \pm 5.7$	$78.6 \pm 10.3$
<b>BMI (kg/m<sup>2</sup>)</b>	$24.5 \pm 3.2$	$24.1 \pm 1.7$	$25.5 \pm 3.1$
<b>Experience (years)</b>	$16.2 \pm 7.0$	$17.5 \pm 8.9$	$12.1 \pm 7.1$

BMI: body mass index.

### 2.3. Data Collection Protocol

A battery of assessments was conducted at six time points: (a) PRE – 30 minutes before the run; (b) POST2h and POST4h – at 2-hour and 4-hour intervals during the run; (c) POST6h – immediately after the 6-hour run; and (d) POST24h and POST48h – at 24 and 48 hours post-exercise, respectively.

The following variables were measured throughout the protocol: (a) anthropometric measures, including height (assessed once before the event) and body mass (recorded at all time points); (b) perceptual responses, including thermal sensation, skin wettedness, thermal comfort, pain, rating of perceived exertion (RPE), and thirst sensation, all assessed using validated subjective scales; (c) cardiovascular responses, including heart rate, systolic pressure, and diastolic pressure; (d) metabolic indicators, assessed via urine analysis for the presence of blood, ketones, glucose, proteins, nitrites, pH level, and urine specific gravity (USG), using reagent strips; and (e) performance, measured as total distance covered in kilometers, continuously monitored through video tracking.

This research protocol was approved by the Ethics Committee of the Federal University of Juiz de Fora (Protocol No. 3.085.114) and was conducted in accordance with the principles outlined in the Declaration of Helsinki.

## **2.4. Measurements**

### *2.4.1 Anthropometrics*

On the day before the event, height was measured using a stadiometer (SECA 213®, Deutschland,  $\pm 0.1$  cm) by an International Society for the Advancement of Kinanthropometry (ISAK) Level 3-certified anthropometrist, following standardized ISAK procedures. Body mass was recorded at all six time points using a portable 3D force plate (Kistler®, Type 9286, Switzerland), with data used to calculate body mass index (BMI) in  $\text{kg/m}^2$ . All measurements were performed under standardized conditions by the same evaluator to ensure consistency and reliability across time points.

### *2.4.2 Perceptual Scales*

All perceptual scales were administered using printed visual forms with clearly labeled options. To ensure standardization and minimize inter-rater variability, all assessments were conducted by the same trained researcher, who also provided verbal clarification when necessary to ensure participant understanding.

#### *2.4.2.1 Thermal Sensation*

Thermal sensation was assessed using a eight-point verbal scale adapted from Young et al. (1987), which ranged from 0 (“unbearably cold”) to 8 (“unbearably hot”), with 4 representing “comfortable”. The scale has been widely used in exercise physiology research to capture fine-grained subjective responses to thermal stress. Participants were asked to indicate their perceived whole-body thermal sensation by selecting the value that best reflected their experience at each assessment moment.

#### *2.4.2.2 Skin Wettedness*

Perceived skin wettedness was assessed using a seven-point bipolar verbal scale adapted from thermal perception research (Olesen & Brager, 2004; Vargas et al., 2018). The scale ranged from  $-3$  (“very dry”) to  $+3$  (“very wet”), with 0 representing a “neutral” sensation. Intermediate descriptors included  $-2$  (“dry”),  $-1$  (“slightly dry”),  $+1$  (“slightly wet”), and  $+2$  (“wet”), allowing participants to express subtle variations in skin wettedness

perception. At each assessment point, participants were instructed to report their overall skin wettedness sensation by selecting the value that best described their perception at that moment.

#### 2.4.2.3 Thermal Comfort

Thermal comfort was evaluated using a five-point verbal descriptor scale ranging from 0 (“very uncomfortable”) to 5 (“very comfortable”), as applied in previous environmental physiology research (Gagge, Stolwijk & Saltin, 1969; Olesen & Brager, 2004; Vargas et al., 2018). Participants were instructed to select the option that best represented their overall sense of thermal comfort at each measurement point.

#### 2.4.2.4 Pain

Pain was assessed using a numerical rating scale (NRS) ranging from 0 to 10, where 0 represented “no pain” and 10 indicated “unbearable pain” (Bennet, 2001; Gift, 1989; Villanueva et al, 2018). Participants were instructed to evaluate their overall pain sensation in the body, according to their perception at the moment. This scale has been widely validated and is commonly used in exercise-induced muscle damage protocols.

#### 2.4.2.5 Rating of Perceived Exertion (RPE)

The subjective perception of effort was assessed using the 10-point Rating of Perceived Exertion (RPE) scale proposed by Foster et al. (2001), which ranges from 0 (“rest”) to 10 (“maximal exertion”). This instrument is widely validated and frequently employed in endurance exercise contexts to estimate internal load. In this study, the RPE was applied at three key time points during the running protocol: at the 2-hour (POST2h), 4-hour (POST4h), and 6-hour (POST6h) marks, immediately following each stage. Participants were instructed to rate their overall exertion by selecting the number that best reflected at that moment.

#### 2.4.2.6 Perceived Recovery Status Scale

The recovery was assessed using the 10-point Perceived Recovery Status (PRS) scale proposed by Laurent et al. (2011), which ranges from 0 (“very poorly recovered/extremely fatigued”) to 10 (“very well recovered/highly energetic”). This tool is validated and commonly used in athletic populations to estimate recovery status between training sessions or competitions. In this study, the PRS was administered at three time

points: before the running (PRE), and at 24 hours (POST24h) and 48 hours (POST48h) following the 6-hour endurance running. Participants were instructed to rate how recovered they felt overall, selecting the number that best represented their perceived recovery state at each respective moment.

#### 2.4.2.7 Thirst Sensation

Thirst sensation was evaluated using a ten-point numerical scale adapted from previous research in hydration and endurance performance. The scale ranged from 0 (“not thirsty at all”) to 10 (“extremely thirsty”), allowing participants to self-assess their subjective perception of thirst (Engell et al., 1987; Greenleaf, 1992; Jiménez & Vargas, 2018).

#### 2.4.3 Cardiovascular responses

Cardiovascular responses were assessed through measurements of heart rate, systolic and diastolic blood pressure at six time points: PRE, POST2h, POST4h, POST6h, POST24h, and POST48h. Heart rate and blood pressure were measured using an automated digital sphygmomanometer (Omron® HEM-7113, Kyoto, Japan), with the cuff placed on the participant’s left arm. All measurements were taken immediately after the athlete left the track and entered the evaluation room, while the participant remained standing and responded simultaneously to the perceptual scales. A single trained evaluator conducted all assessments to ensure consistency and reduce inter-rater variability. The device was calibrated according to the manufacturer’s specifications prior to each data collection period, and environmental conditions in the evaluation room were maintained constant throughout the study.

#### 2.4.4 Metabolic analysis (urinalysis)

Urine samples were collected at six time points (PRE, POST2h, POST4h, POST6h, POST24h, and POST48h) to evaluate hydration status and detect potential metabolic disturbances induced by prolonged exertion. Participants were instructed to void directly into sterile, pre-labeled collection containers provided by the research team. All samples were analyzed within two hours of collection to minimize compositional alterations, in accordance with reagent strip handling recommendations.

*Urinalysis* was performed using URI-TOP® 11 test strips (Biosynex S.A., Illkirch-Graffenstaden, France; REF 1040010), following the manufacturer’s protocol. Each strip was immersed in the sample for 2–3 seconds and then gently blotted on absorbent paper

to remove excess urine. After exactly 60 seconds, the colorimetric changes were photographed next to the reference scale provided by the manufacturer, under good lighting conditions. The evaluated parameters included: blood, ketones, glucose, proteins, nitrites, pH, and urine specific gravity (USG).

All evaluations were performed by the same trained researcher to ensure consistency across time points. This analysis enabled rapid, noninvasive monitoring of hydration, and metabolic stress in response to prolonged physical activity.

#### ***2.4.5 Performance – Distance covered***

Total distance covered during the 6-hour endurance running event protocol was quantified through continuous video recording using a Sony® DCR-SR37 digital video camera (Japan), which tracked lap completion times for each participant. The test took place on an outdoor, standardized 400-meter track and began at 8:15 a.m. Participants started individually at 2-minute intervals, based on a randomized bib number order assigned the day before to optimize intermediate data collection. A pre-recorded audio track, broadcast via a sound system, provided real-time individualized instructions. The recording alerted athletes (by bib number) to: (a) start the race; (b) refrain from eating 15 minutes prior to intermediate data collection; (c) report to the research station for intermediate assessments; (d) return to the track after the 15-minute interval; and (e) conclude the event.

Athletes self-selected their pacing strategy and wore personal running attire consisting of shorts and short-sleeved shirts. Each participant was assigned an individual station located along the main straight of the track, identified by their bib number. These stations provided ad libitum access to chocolate, cereal bars, bananas, and bottle water. Bathroom breaks were allowed at any time but were typically taken during the scheduled 15-minute intervals to minimize interference with data collection.

#### ***2.5 Statistical analysis***

All statistical analyses were performed using SPSS® (Version 21; IBM Corp., Armonk, NY, USA). Descriptive statistics were calculated and presented as mean  $\pm$  standard deviation (SD) to summarize central tendency and variability of all measured variables. Normality of data distribution was assessed using the Shapiro-Wilk test. Between-group differences were evaluated via one-way ANOVA, with Tukey's post-hoc test applied for pairwise comparisons where appropriate. The Greenhouse-Geisser

correction was employed to adjust for violations of sphericity in repeated-measures analyses. Effect sizes were quantified using partial eta-squared ( $\eta^2$ ), and all inferential tests were interpreted with statistical significance  $p \leq 0.05$ .

### 3. Results

The analysis showed significant intergroup differences in several variables, as detailed below. For the body mass, we observed an interaction effect between Group X moment of measurement ( $F_{2,38}=1.947$ ;  $p=0.042$ ;  $\eta^2=0.098$ ). However, the post-hoc test doesn't locate the group differences. About the moment of measurement, Ultra group showed differences between the means observed at Pre vs. 2h [-1.2 kg (-1.7; -0.6;  $p \leq 0.001$ )], 4h [-1.8 kg (-2.5; -1.1;  $p \leq 0.001$ )] and 6h [-1.8 kg (-2.5; -1.0;  $p \leq 0.001$ )]; 2h vs. 4h [-0.7 kg (-1.1; -0.2;  $p=0.001$ )], 6h [-0.6 kg (-1.1; -0.1;  $p=0.006$ )] and 48h [1.1 kg (0.2; 1.9;  $p=0.005$ )]; 24h vs. 4h [1.1 kg (0.2; 2.0;  $p=0.008$ )] and 6h [1.7 kg (0.9; 2.6;  $p \leq 0.001$ )]. 48h vs. 4h [1.0 kg (0.9; 2.6;  $p=0.005$ )] and 6h [1.7 kg (0.9; 2.5;  $p \leq 0.001$ )]. Marathon group showed differences between means observed at Pre vs. 2h [-1.1 kg (-1.6; -0.6;  $p \leq 0.001$ )], 4h [-1.4 kg (-2.0; -0.8;  $p \leq 0.001$ )], 6h [-1.3 kg (-1.9; -0.7;  $p \leq 0.001$ )] and 24h [-0.7 kg (-1.3; -0.4;  $p=0.031$ )]. For the Sub-marathon group, we observed significative differences between the means measured at Pre vs. 4h [-0.9 kg (-1.6; -0.2;  $p=0.007$ )] and 6h [-0.9 kg (-1.6; -0.3;  $p=0.002$ )]. 48h vs. 4h [0.8 kg (0.0; 1.6;  $p=0.05$ )] and 6h [0.9 kg (0.1; 1.7;  $p=0.013$ )].

For thermal sensation there was an isolated effect of moment of measurement ( $F_{2,38}=20.526$ ;  $p \leq 0.001$ ;  $\eta^2=0.726$ ). For this perceptual scale, the means observed at Pre moment showed a significative difference for those observed at 2h [1.4 a.u. (0.8; 2.0;  $p \leq 0.001$ )], 4h [1.5 a.u. (1.0; 2.0;  $p \leq 0.001$ )], 6h [1.1 a.u. (0.7; 1.6;  $p \leq 0.001$ )] and 24 h [0.5 a.u. (0.0; 1.0;  $p=0.034$ )]. 24 h vs 2h [-0.9 a.u. (-1.4; -0.4;  $p \leq 0.001$ )], 4h [-1.0 a.u. (-1.6; -0.5;  $p \leq 0.001$ )] and 6h [-0.6 a.u. (-1.1; -0.1;  $p=0.01$ )], similar results were observed for 48h vs 2h [-1.1 a.u. (-1.6; -0.5;  $p \leq 0.001$ )], 4h [-1.2 a.u. (-1.8; -0.6;  $p \leq 0.001$ )], 6h [-0.8 a.u. (-1.3; -0.2;  $p=0.001$ )].

The analysis for the skin wettedness sensation indicated an isolated effect for the moment of measurement ( $F_{2,38}=15.366$ ;  $p \leq 0.001$ ;  $\eta^2=0.706$ ), where the means observed at Pre moment showed a significant difference when compared to 2h [1.3 a.u. (0.7; 2.0;  $p \leq 0.001$ )], 4h [1.3 a.u. (0.4; 2.3;  $p=0.002$ )] and 6h [0.8 a.u. (0.0; 1.6;  $p=0.038$ )]. 24 h showed a significant difference vs. 2h [-1.7 a.u. (-2.4; -1.0;  $p \leq 0.001$ )], 4h [-1.7 a.u. (-2.5; -0.8;  $p \leq 0.001$ )] and 6h [-1.2 a.u. (-1.9; -0.5;  $p \leq 0.001$ )]. 48h showed too differences vs 2h [-1.5



a.u. (-2.2; -0.8;  $p \leq 0.001$ ), 4h [-1.5 a.u. (-2.4; -0.7;  $p \leq 0.001$ )] and 6h [-1.0 a.u. (-1.8; -0.2;  $p = 0.005$ )).

Thermal comfort perceived scale presented a significant and isolated effect of moment of measurement ( $F_{2,38} = 13.983$ ;  $p \leq 0.001$ ;  $\eta^2 = 0.686$ ). For this measurement, the means observed at Pre moment present a significative difference vs those observed at 2h [1.3 a.u. (0.7; 2.0;  $p \leq 0.001$ ), 4h [1.3 a.u. (0.4; 2.3;  $p = 0.002$ ) and 6h [0.8 a.u. (0.0; 1.6;  $p = 0.038$ )]. Furthermore; 24 h showed a significant difference vs. 2h [0.9 a.u. (0.5; 1.3;  $p \leq 0.001$ ), 4h [1.1 a.u. (0.6; 1.6;  $p \leq 0.001$ ) and 6h [1.1 a.u. (0.5; 1.7;  $p \leq 0.001$ )]. At the last, 48h showed differences vs 2h [0.9 a.u. (0.4; 1.4;  $p \leq 0.001$ ), 4h [1.1 a.u. (0.6; 1.6;  $p \leq 0.001$ ) and 6h [1.1 a.u. (0.4; 1.7;  $p \leq 0.001$ )].

Finally, for the thirst sensation; we observed an isolated effect of the moment of measurement ( $F_{2,38} = 13.831$ ;  $p \leq 0.001$ ;  $\eta^2 = 0.684$ ). For this perceptual scale, the means observed at Pre moment presented a significative difference vs. those measured at 2h [1.4 a.u. (0.5; 2.3;  $p \leq 0.001$ ), 4h [2.0 a.u. (1.0; 3.0;  $p \leq 0.001$ )] and 6h [1.8 a.u. (0.6; 3.0;  $p = 0.001$ )]. 4h differed for the 24h [-1.5 a.u. (-2.6; -0.4;  $p = 0.002$ )] and 48 h [-2.2 a.u. (-3.0; -1.3;  $p = 0.001$ )]. 48 h showed a significative difference vs. 2h [-1.5 a.u. (-2.3; -0.7;  $p = 0.001$ )] and 6h [-2.0 a.u. (-3.2; -0.7;  $p = 0.001$ )]. Table 2 showed the results of body mass, and perceptual scales before, during and after the 6-hour endurance running.

**Table 2.** Body mass, thermal sensation, skin wettedness, thermal comfort, pain, thirst, measured at Pre, 2h, 4h, 6h of the race and 24h and 48h after the race.

	Body Mass (kg)					
	Pre	2 hours	4 hours	6 hours	24h after	48h after
Ultra	74.8±10.2 <sup>a</sup>	73.7±10.4 <sup>b</sup>	73.0±10.2 <sup>c</sup>	73.1±10.1 <sup>c</sup>	74.1±10.3 <sup>d</sup>	74.8±10.1
Marathon	77.2±5.7 <sup>e</sup>	76.1±5.8 <sup>d</sup>	75.8±5.7 <sup>d</sup>	75.9±5.4 <sup>d</sup>	76.5±5.6 <sup>d</sup>	77.1±5.8
Sub-marathon	78.6±10.3 <sup>f</sup>	78.1±10.4	77.8±10.3 <sup>d</sup>	77.7±10.4 <sup>d</sup>	78.5±10.8	78.6±10.4
	Thermal Sensation					
	Pre	2 hours	4 hours	6 hours	24h after	48h after
Ultra	3.6±0.7 <sup>g</sup>	5.0±1.2	5.5±0.9	5.2±1.1	4.3±0.8 <sup>a</sup>	4.1±0.8 <sup>a</sup>
Marathon	3.4±0.6 <sup>g</sup>	4.9±0.8	5.1±1.1	4.5±0.7	3.9±0.6 <sup>a</sup>	3.9±0.5 <sup>a</sup>
Sub-marathon	3.7±0.7 <sup>g</sup>	5.0±0.6	4.8±0.8	4.3±0.9	4.0±0.4 <sup>a</sup>	3.8±0.5 <sup>a</sup>
	Skin Wettedness					
	Pre	2 hours	4 hours	6 hours	24h after	48h after
Ultra	-1.2±1.0 <sup>a</sup>	0.5±1.3	0.5±1.3	0.0±1.5	-1.5±0.9 <sup>a</sup>	-1.5±0.9 <sup>a</sup>
Marathon	-0.9±1.0 <sup>a</sup>	0.4±1.0	0.5±1.8	-0.6±1.0	-1.6±0.6 <sup>a</sup>	-1.2±0.8 <sup>a</sup>
Sub-marathon	-1.2±0.9 <sup>a</sup>	-0.3±1.1	-0.3±1.4	-0.3±1.1	-1.3±0.8 <sup>a</sup>	-1.2±0.7 <sup>a</sup>
	Thermal Comfort					
	Pre	2 hours	4 hours	6 hours	24h after	48h after
Ultra	3.5±0.9 <sup>a</sup>	2.9±0.7	2.2±1.1	2.7±0.6	3.7±0.5 <sup>a</sup>	4.0±0.6 <sup>a</sup>
Marathon	3.9±0.7 <sup>a</sup>	2.8±1.0	3.0±1.2	2.8±1.3	3.9±0.4 <sup>a</sup>	3.8±0.7 <sup>a</sup>
Sub-marathon	3.8±0.7 <sup>a</sup>	3.2±0.8	3.1±0.7	2.8±0.9	3.9±0.3 <sup>a</sup>	3.8±0.5 <sup>a</sup>
	Thirst					
	Pre	2 hours	4 hours	6 hours	24h after	48h after
Ultra	2.3±1.6 <sup>a</sup>	3.7±1.8	5.3±1.4 <sup>c</sup>	4.1±2.7	2.5±1.7	2.2±0.8 <sup>n</sup>

Marathon	2.0±1.1 <sup>a</sup>	3.5±1.2	4.0±1.9 <sup>c</sup>	4.3±2.2	2.6±1.7	1.8±0.9 <sup>h</sup>
Sub-marathon	2.6±2.4 <sup>a</sup>	3.8±2.0	3.6±1.8 <sup>c</sup>	3.9±1.9	3.2±1.6	2.4±1.6 <sup>h</sup>

<sup>a</sup>  $p \leq 0.038$  vs. 2h, 4h and 6h. <sup>b</sup>  $p \leq 0.06$  vs. 4h, 6h and 48h. <sup>c</sup>  $p \leq 0.034$  vs. 24h and 48h. <sup>d</sup>  $p \leq 0.05$  vs. 48h. <sup>e</sup>  $p \leq 0.034$  vs. The others except 48h. <sup>f</sup>  $p \leq 0.007$  vs. 4h and 6h. <sup>g</sup>  $p \leq 0.034$  vs. 2h, 4h, 6h and 24h. <sup>h</sup>  $p = 0.001$  vs. 2h and 6h.

For RPE ( $F_{2,38}=32.476$ ;  $p \leq 0.001$ ;  $\eta^2=0.65$ ) and PRS ( $F_{2,38}=12.17$ ;  $p \leq 0.001$ ;  $\eta^2=0.41$ ) we observed isolated effect of moment of measurement. For RPE, the means observed at 2h were statistically lower than 4h [-1.5 a.u. (-2.0; -1.0;  $p \leq 0.001$ )] and 6h [-2.3 a.u. (-3.1; -1.5;  $p \leq 0.001$ )], and the means observed at 4h were statistically lower than 6h [-0.8 a.u. (-1.5; -0.2;  $p = 0.008$ )]. For PRS 48h showed a significant lower recovery than PRE [1.5 a.u. (0.5; 2.4;  $p = 0.001$ )] and 24h [1.2 a.u. (0.5; 1.9;  $p \leq 0.001$ )].

For pain there was a significative and isolated effect for moment of measurement ( $F_{2,38}=55.446$ ;  $p \leq 0.001$ ;  $\eta^2=0.897$ ). Where the PRE showed significant difference for all moments of measurement ( $p \leq 0.001$ ). 2h showed significative difference for all consecutive moments ( $p \leq 0.044$ ) except for 48h ( $p = 0.191$ ). 4h showed difference for 24h [1.1 a.u. (0.0; 2.2;  $p = 0.044$ )] and 48 h [2.7 a.u. (1.7; 3.8;  $p \leq 0.001$ )]. 6h showed too difference for 24h [1.8 a.u. (0.8; 2.9;  $p \leq 0.001$ )] and 48 h [3.5 a.u. (2.4; 4.6;  $p \leq 0.001$ )]. Table 3 showed the results for perceived pain, before, during and after 6-hour endurance running.

**Table 3.** Perceived pain before, along and after 6 h running.

	Pain					
	Pre	2 hours	4 hours	6 hours	24h after	48h after
Ultra	0.5±0.8 <sup>a</sup>	3.6±1.4 <sup>b</sup>	6.0±2.0 <sup>c</sup>	6.8±1.9 <sup>c</sup>	5.0±1.7	3.2±1.5
Marathon	1.1±1.6 <sup>a</sup>	3.6±1.5 <sup>b</sup>	5.3±1.9 <sup>c</sup>	6.0±1.7 <sup>c</sup>	4.4±1.5	2.6±1.5
Sub-marathon	1.0±1.0 <sup>a</sup>	2.9±1.1 <sup>b</sup>	5.0±1.5 <sup>c</sup>	5.7±1.8 <sup>c</sup>	3.6±1.4	2.3±1.4

<sup>a</sup>  $p \leq 0.001$  vs the others. <sup>b</sup>  $p \leq 0.044$  vs the others except 48h. <sup>c</sup>  $p \leq 0.044$  this moment of measurement vs. 24 and 48h.

Heart rate (HR) showed an isolated effect for moment of measurement ( $F_{2,38}=51.387$ ;  $p \leq 0.001$ ;  $\eta^2=0.889$ ). HR at PRE showed differences for 2h [-45.0 bpm (-54.7; -35.3;  $p \leq 0.001$ )]; 4h [-40.2 bpm (-51.0; -29.4;  $p \leq 0.001$ )]; 6h [-37.1 bpm (-47.9; -26.3;  $p \leq 0.001$ )]. 24h showed a significative difference for 2h [-39.7 bpm (-51.1; -28.3;  $p \leq 0.001$ )]; 4h [-34.9 bpm (-45.2; -24.5;  $p \leq 0.001$ )]; 6h [-31.8 bpm (-40.4; -23.1;  $p \leq 0.001$ )] and 48h [9.5 bpm (3.5; 15.4;  $p \leq 0.001$ )]. Systolic blood pressure (SBP) showed too an isolated effect for moment of measurement ( $F_{2,38}=7.055$ ;  $p \leq 0.001$ ;  $\eta^2=0.524$ ). The SBP at PRE presented

significant difference to 2h [15.9 mmHg. (3.0; 28.8;  $p=0.007$ ); 4h [17.0 mmHg (6.4; 27.6;  $p\leq 0.001$ ); 6h [14.8 mmHg (4.2; 25.4;  $p=0.002$ )] and 24h [10.9 mmHg (1.3; 20.4;  $p=0.016$ )). 48h showed difference to 4h [11.1 mmHg (2.0; 20.1;  $p=0.007$ ) and 6h [8.8 mmHg (0.6; 17.1;  $p=0.026$ )). Similar results were observed to diastolic blood pressure (DBP), where we find an isolated effect of moment of measurement ( $F_{2,38}=4.089$ ;  $p=0.006$ ;  $\eta^2=0.39$ ). The means observed at PRE showed a significant difference to 2h [8.6 mmHg. (2.3; 14.9;  $p=0.002$ ); 4h [11.0 mmHg (2.0; 20.0;  $p=0.007$ ); 6h [9.1 mmHg (2.0; 16.1;  $p=0.004$ )] and 24h [6.2 mmHg (0.6; 11.9;  $p=0.022$ )). Table 4 presents the results for heart rate and blood pressure before, during and after 6-hour endurance running.

**Table 4.** Heart rate, systolic and diastolic blood pressure measured at Pre, 2h, 4h, 6h of the race and 24h and 48h after.

	Heart Rate (bpm)					
	Pre	2 hours	4 hours	6 hours	24h after	48h after
Ultra	71.6±12.3 <sup>a</sup>	121.7±15.5	115.6±15.6	117.5±11.1	81.5±14.8 <sup>b</sup>	68.4±9.9
Marathon	72.6±13.0 <sup>a</sup>	117.3±17.4	112.4±16.6	107.9±16.5	72.5±13.6 <sup>b</sup>	63.9±12.7
Sub-marathon	67.7±10.3 <sup>a</sup>	107.9±16.8	104.3±21.3	97.7±20.7	73.8±11.2 <sup>b</sup>	67.2±13.0
	Systolic Blood Pressure (mmHg)					
	Pre	2 hours	4 hours	6 hours	24h after	48h after
Ultra	136.4±5.5 <sup>c</sup>	113.0±36.4	111.5±12.1	123.4±12.7	128.5±11.4	128.2±6.2 <sup>d</sup>
Marathon	131.7±20.2 <sup>c</sup>	120.1±14.3	114.6±16.6	114.9±14.1	119.7±12.7	129.5±11.5 <sup>d</sup>
Sub-marathon	135.9±18.5 <sup>c</sup>	123.1±20.9	126.9±11.5	121.3±17.7	123.3±13.2	128.4±11.3 <sup>d</sup>
	Diastolic Blood Pressure (mmHg)					
	Pre	2 hours	4 hours	6 hours	24h after	48h after
Ultra	86.5±4.6 <sup>c</sup>	74.4±6.3	73.0±8.6	75.0±14.0	82.2±7.8	79.4±5.8
Marathon	88.8±10.6 <sup>c</sup>	78.6±6.2	71.4±17.6	78.6±8.2	80.0±9.1	84.5±6.5
Sub-marathon	88.2±13.3 <sup>c</sup>	84.7±11.3	86.1±8.4	82.8±9.3	82.7±9.5	84.1±8.6

<sup>a</sup>  $p\leq 0.001$  this moment of measurement vs. 2, 4 and 6h. <sup>b</sup>  $p\leq 0.001$  vs the others except Pre. <sup>c</sup>  $p\leq 0.022$  vs the others except 48h. <sup>d</sup>  $p\leq 0.026$  this moment of measurement vs. 4 and 6h.

No blood and nitrites were detected in the urine; therefore, no inferential analyses were conducted for these variables. For ketones, a main effect of time of measurement was observed ( $F_{1,36} = 4.227$ ;  $p = 0.001$ ;  $\eta^2 = 0.1$ ); however, the statistical test lacked sufficient power to identify significant differences. Regarding glucose, after applying the Greenhouse-Geisser correction, a Group  $\times$  Time interaction effect was observed ( $F_{1,36} = 2.838$ ;  $p = 0.022$ ;  $\eta^2 = 0.136$ ). The Sub-marathon group showed a significant difference between the 24-hour measurement and the other time points ( $p \leq 0.05$ ), except for PRE [16.7 (−0.7; 34.1);  $p = 0.07$ ]. For between-group comparisons, the post hoc test was not able to detect significant differences.

For protein presence, a main effect of time of measurement was observed ( $F_{5,31} = 14.105$ ;  $p \leq 0.001$ ;  $\eta^2 = 0.695$ ), with significant differences at 6 h and 24 h compared to the other time points ( $p \leq 0.032$ ).

A main effect of time of measurement was observed for urine pH ( $F_{5,32} = 11.617$ ;  $p \leq 0.001$ ;  $\eta^2 = 0.645$ ). PRE differed significantly from 2 h [2.3 (−0.3; 4.3);  $p = 0.016$ ], and both 2 h and 4 h showed significant differences compared to the 6 h, 24 h, and 48 h time points ( $p \leq 0.003$ ). Finally, a main effect of time of measurement was observed for urine specific gravity (USG) ( $F_{5,32} = 11.617$ ;  $p \leq 0.001$ ;  $\eta^2 = 0.645$ ), for this variable, the PRE differed significantly from 2 h [−0.005 (−0.009; −0.0);  $p = 0.032$ ]; 6 h differed significantly from PRE [0.007 (0.002; 0.012);  $p = 0.002$ ], 24 h [0.004 (0.0; 0.007);  $p = 0.037$ ], and 48 h [0.007 (0.002; 0.012);  $p \leq 0.001$ ]. Table 5 presents the results for the variables measured in urine before, during and after 6h endurance running.

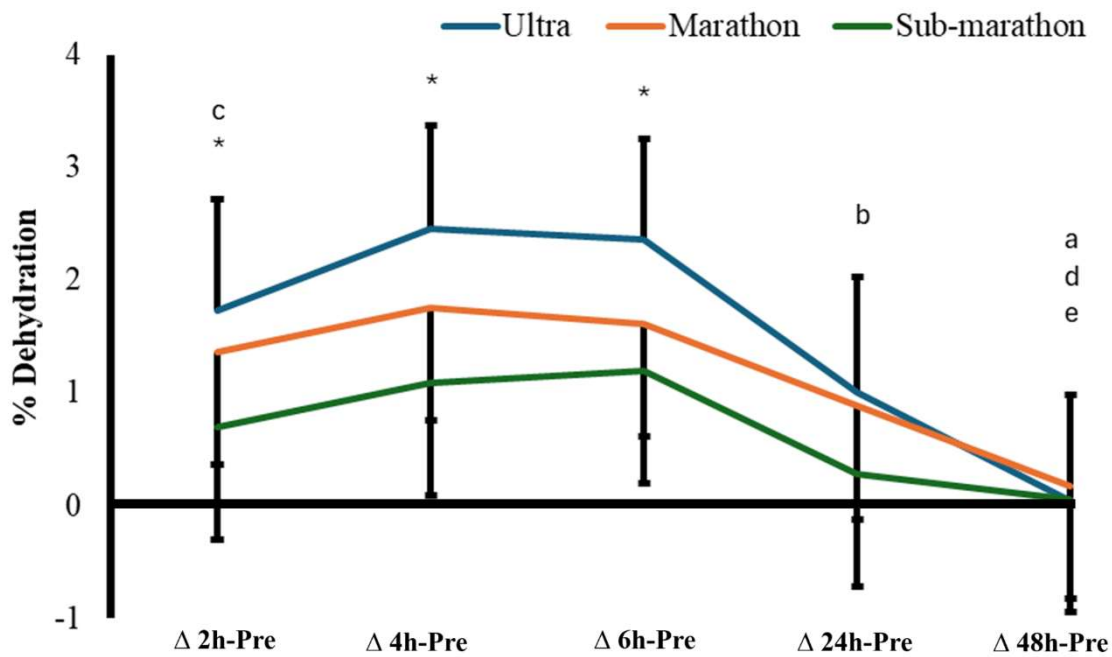
**Table 5.** Results for the variables measured in urine (blood, ketones, glucose, proteins, nitrites, pH, urine specific gravity) at Pre, 2h, 4h, 6h of the race and 24h and 48h after.

	PRE	2 hours	4 hours	6 hours	24h after	48h after
Blood ( <i>RBC/μL</i> ; glóbulos vermelhos por microlitro)						
Ultra	0±0	0±0	0±0	0±0	0±0	0±0
Marathon	0±0	0±0	0±0	0±0	0±0	0±0
Sub-Marathon	0±0	0±0	0±0	0±0	0±0	0±0
Ketones (mg/dL)						
Ultra	0±0	0±0	0±0	2.7±6.1	0±0	0±0
Marathon	0±0	0±0	0±0	1.9±5.0	0±0	0±0
Sub-Marathon	0±0	0±0	0±0	0±0	0±0	0±0
Glucose (mg/dL)						
Ultra	0±0	0±0	0±0	4.5±15.1	4.5±15.1	0±0
Marathon	0±0	0±0	0±0	0±0	6.3±17.1	3.1±12.5
Sub-Marathon	8.3±19.5	0±0	0±0	4.2±14.4	25.0±26.0 <sup>a</sup>	0±0
Proteins (mg/dL)						
Ultra	0±0	0±0	2.7±9.0	22.7±29.7 <sup>b</sup>	24.5±12.1 <sup>b</sup>	2.7±9.0
Marathon	0±0	0±0	0±0	21.3±24.3 <sup>b</sup>	18.0±15.2 <sup>b</sup>	2.0±7.7
Sub-Marathon	5.0±11.7	2.5±8.7	0±0	12.5±15.4 <sup>b</sup>	20.0±14.8 <sup>b</sup>	2.5±8.7
Nitrites (Positive/Negative)						

Ultra	0±0	0±0	0±0	0±0	0±0	0±0
Marathon	0±0	0±0	0±0	0±0	0±0	0±0
Sub-Marathon	0±0	0±0	0±0	0±0	0±0	0±0
pH (unitless)						
Ultra	5.2±2.6 <sup>c</sup>	3.0±3.5 <sup>d</sup>	5.1±2.5 <sup>d</sup>	6.4±0.5	6.3±0.5	6.3±0.5
Marathon	5.7±1.5 <sup>c</sup>	2.3±3.0 <sup>d</sup>	2.6±3.1 <sup>d</sup>	6.0±0.4	5.7±1.5	6.1±0.3
Sub-Marathon	5.4±1.9 <sup>c</sup>	4.2±2.6 <sup>d</sup>	4.8±2.4 <sup>d</sup>	5.7±0.5	6.1±0.5	6.2±0.7
Urine Specific Gravity (g.mL <sup>-1</sup> )						
Ultra	1.019±0.001 <sup>c</sup>	1.024±0.002	1.024±0.009	1.027±0.004 <sup>e</sup>	1.022±0.007	1.017±0.001
Marathon	1.022±0.001 <sup>c</sup>	1.025±0.004	1.027±0.004	1.027±0.005 <sup>e</sup>	1.027±0.004	1.024±0.008
Sub-Marathon	1.022±0.001 <sup>c</sup>	1.027±0.005	1.029±0.014	1.029±0.001 <sup>e</sup>	1.022±0.007	1.020±0.01

<sup>a</sup>  $P \leq 0.05$  vs. other time points except PRE; <sup>b</sup>  $P \leq 0.05$  vs. other time points; <sup>c</sup>  $P \leq 0.033$  vs. 2h; <sup>d</sup>  $P \leq 0.003$  vs. 6h, 24h, and 48h; <sup>e</sup>  $P \leq 0.037$  vs. PRE, 24h, and 48h.

Figure 1 showed the percentage of dehydration along the running, 24 and 48h after for 3 groups. For this measure, after applying the Greenhouse-Geisser correction, we observed an interaction effect between Group X moment of measurement ( $F_{2,38}=2.102$ ;  $p=0.039$ ;  $\eta p^2=0.105$ ). Ultra showed differences between  $\Delta 48h$ -Pre and other moments ( $p \leq 0.001$ ).  $\Delta 24h$ -Pre showed difference vs. other moments of measurement ( $p=0.253$ ).  $\Delta 2h$ -Pre showed difference vs.  $\Delta 4h$ -Pre [-0.7% (-1.2; -0.2;  $p=0.003$ )] and  $\Delta 6h$ -Pre [-0.6% (-1.2; -0.1;  $p=0.024$ )]. For Marathon, we observed differences between  $\Delta 48h$ -Pre and other moments ( $p \leq 0.012$ ). Sub-marathon present differences between  $\Delta 48h$ -Pre and  $\Delta 4h$ -Pre [-1.0% (-2.0; -0.0;  $p=0.043$ )] and  $\Delta 6h$ -Pre [-1.1% (-2.1; -0.2;  $p=0.008$ )]. About group comparison, at  $\Delta 2h$ -Pre [1.0% (0.1; 1.9;  $p=0.015$ )],  $\Delta 4h$ -Pre [1.4% (0.3; 2.4;  $p=0.008$ )],  $\Delta 6h$ -Pre [1.2% (0.2; 2.2;  $p=0.018$ )] Ultra showed differences vs. Sub-marathon.



**Figure 1.** Percentage of dehydration during and after running for Ultra, Marathon and Sub-marathon groups. <sup>a</sup>  $p \leq 0.001$  vs. others for Ultra. <sup>b</sup>  $p \leq 0.002$  vs. others except  $\Delta 2h\text{-Pre}$  for Ultra. <sup>c</sup>  $p \leq 0.024$  vs.  $\Delta 4h\text{-Pre}$  and  $\Delta 6h\text{-Pre}$  for Ultra. <sup>d</sup>  $p \leq 0.012$  vs. others for Marathon. <sup>e</sup>  $p \leq 0.043$  vs.  $\Delta 4h\text{-Pre}$  and  $\Delta 6h\text{-Pre}$  for Sub-marathon. \*  $p \leq 0.018$  Ultra vs. Sub-marathon.

#### 4. Discussion

This study examined cardiovascular, metabolic, and perceptual responses in trained male runners before, during, and after a 6-hour endurance running. Participants were retrospectively categorized into three performance-based groups according to total distance covered: sub-marathoners (<40 km), marathoners (40–44 km), and ultramarathoners (>44 km). The main findings indicate that runners who covered greater distances, particularly those in the ultramarathon group, exhibited more pronounced physiological strain and a slower recovery profile. Notably, these participants showed greater reductions in body mass, sustained elevations in heart rate and perceived discomfort, and delayed normalization of both hemodynamic and perceptual parameters at 24 and 48 hours post-exercise. These results suggest that total running volume, even under ad libitum hydration conditions, plays a key role in the magnitude and duration of physiological disruption following ultra-endurance efforts.

Among the most relevant physiological changes observed, the reduction in body mass stood out as a key indicator of fluid loss and exercise-induced dehydration. Despite ad libitum access to hydration throughout the protocol, ultramarathoners exhibited

significantly greater reductions in body mass compared to the sub-marathon and marathon groups, and their values remained below baseline even 48 hours post-exercise. These findings are consistent with previous studies (Francisco et al., 2024; Goulet et al., 2023; Hoffman & Stuempfle, 2014; Hoffman, Goulet & Maughan, 2018; Racinais et al., 2021) showing that the magnitude of body mass loss correlates with exercise duration, sweat rate, and insufficient fluid replacement in prolonged efforts. The persistence of reduced body mass after 48 hours suggests incomplete rehydration and reinforces the need for individualized recovery strategies based on running volume and post-exercise hydration behavior.

In addition to fluid loss, prolonged cardiovascular strain was evident in the ultramarathon group, as reflected by sustained elevations in heart rate and delayed normalization of blood pressure values. Although all groups experienced increased heart rate during the run, only the ultramarathoners showed elevated values persisting at 24 hours post-exercise, suggesting a slower cardiovascular recovery. These findings align with previous research indicating that prolonged endurance exercise can lead to transient autonomic imbalance, characterized by elevated sympathetic activity and reduced vagal tone during recovery (Adams et al., 2016; Lima et al., 2024; Mann et al., 2015; Paech et al., 2021). Moreover, the delayed return of blood pressure to baseline observed in some participants may reflect residual hypovolemia or impaired vascular tone, both of which are common after ultra-endurance events (Goulet et al., 2023; Hammer et al., 2024). Together, these cardiovascular responses highlight the physiological cost of prolonged effort and reinforce the importance of post-race monitoring, particularly in athletes exposed to long-duration events.

Perceptual responses provided additional insight into the internal load and recovery of the athletes. As expected, ratings of pain, exertion, thirst, and thermal discomfort increased progressively throughout the 6-hour run in all groups, but were notably more intense and prolonged in the ultramarathon group. Pain perception, in particular, remained elevated even at 48 hours post-exercise, suggesting extended neuromuscular strain and a delayed recovery process.

These findings reinforce the value of perceptual measures as noninvasive tools for monitoring stress in endurance athletes, especially in field conditions where physiological monitoring may be limited (Borg, 1982; Gibson et al., 2006). The integration of bottom-up physiological signals (e.g., dehydration, muscular fatigue) with top-down cognitive processing likely contributed to the subjective burden reported, as supported by models of

centrally regulated effort (Costa et al., 2019; Venhorst, Micklewright & Noakes, 2018). Collectively, the perceptual data aligned with the objective physiological markers, underscoring the need for integrated monitoring approaches during and after ultra-endurance exercise.

Thermal perception and skin wettedness ratings increased progressively during the endurance running event, reflecting the combined effect of environmental exposure, metabolic heat production, and sweat accumulation. However, no significant differences were observed between performance groups for these variables, suggesting that thermal discomfort and perceived moisture were more strongly influenced by ambient conditions and duration of exposure than by total distance covered. Similar patterns have been reported in endurance events conducted under moderate-to-warm temperatures, where subjective thermal stress rises consistently across individuals regardless of performance level (Goulet et al., 2023; Kajiki et al., 2024). It is likely that the use of lightweight clothing, access to hydration *ad libitum*, and self-paced strategies helped modulate thermal strain perceptual during the test (Francisco et al. 2024). Despite the absence of between-group differences, the progressive increase in thermal and wettedness sensations during the run may have contributed to perceived exertion and behavioral adjustments such as pacing or fluid intake. These findings support the inclusion of perceptual thermal assessments as complementary markers of internal load in endurance running.

Coaches and sports scientists should consider integrating perceptual indicators, such as pain, comfort, recovery, and exertion scales, into daily monitoring routines, as they may provide early warning signs of incomplete recovery. Moreover, since body mass did not return to baseline even 48 hours post-race in some participants, structured hydration protocols may be necessary beyond the immediate post-exercise period. Altogether, these insights highlight the need for personalized recovery planning that goes beyond generic timelines, especially in scenarios involving prolonged and self-paced endurance running.

## **5. Limitations**

Despite the relevance of the findings, this study presents some limitations that should be acknowledged. First, the sample consisted exclusively of trained male military, which limits the generalizability of the results to recreational runners, female athletes, or civil populations with different training backgrounds. Second, the grouping of participants based on performance may have introduced variability in physiological preparedness across groups, despite baseline homogeneity. Third, although the perceptual scales



provided interesting subjective information, their interpretation may be influenced by individual pain tolerance, prior experience, cognitive bias, or interest in contributing to the research.

Finally, urine analysis was limited to semiquantitative reagent strips, which, despite being practical for field settings, lack the precision of laboratory based assessments such as urine osmolality or electrolyte concentration. Future studies should consider incorporating these more accurate measures to enhance the reliability of hydration and metabolic status evaluation.

## **6. Practical Applications**

The findings of this study have important practical implications for endurance athletes, coaches, and support staff involved in training prescription and recovery. The delayed normalization of both physiological and perceptual markers, particularly among ultramarathoners, suggests that recovery strategies should be individualized based on running volume and athlete profile.

Athletes engaging in ultra endurance running may require recovery periods longer than 24 hours, with close attention to hydration status, neuromuscular recovery, and cardiovascular function. Perceptual scales such as pain, exertion, and thermal sensation, alongside body mass tracking, offer practical and accessible tools for monitoring recovery, especially during the endurance running where advanced equipment may be unavailable. Notably, some variables remained altered even after 48 hours, suggesting that tracking discomfort and RPE in the days following competition can help prevent overreaching and support informed training adjustments.

Future research should include more diverse populations (e.g., women, recreational runners) and explore biomarkers like sweat sodium, osmolality, and creatine kinase to improve the understanding of fatigue and recovery. Testing recovery interventions such as hydration strategies or cold-water immersion could further enhance post-race care.

Overall, integrating physiological and perceptual markers into training and competition offers a low-cost and efficient way to optimize performance and protect athlete health after prolonged endurance running.

## **7. Conclusions**

In conclusion, this study demonstrates that higher performance during prolonged endurance running is associated with more intense and sustained physiological and

perceptual disruptions, even under self-paced and hydrated conditions. Ultramarathoners experienced greater reductions in body mass, higher heart rate levels, and greater perceptual discomfort throughout the recovery period, with several variables remaining altered up to 48 hours post-exercise.

These findings suggest that total running volume is a critical determinant of recovery, and that recovery strategies should be adapted based on individual performance profiles. The integration of cardiovascular, metabolic, and perceptual markers across diferentes time points reinforces the importance of multidimensional monitoring in ultra-endurance running, offering insights for practitioners involved in the management, recovery, and performance optimization of athletes.

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## CONSIDERAÇÕES FINAIS

Esta tese teve como objetivo analisar as respostas fisiológicas e perceptuais durante e após uma corrida contínua de 6 horas, com ênfase na termorregulação e foco específico na dinâmica da temperatura da pele ao longo do esforço prolongado. O estudo envolveu 39 soldados de elite submetidos a uma situação real de corrida de longa duração, sob condições ambientais de calor, possibilitando a coleta de dados em diferentes momentos do esforço e da recuperação.

Os resultados mostraram que variáveis como a percepção de esforço, bem como a temperatura da coxa, se correlacionam inversamente com a distância percorrida. Esses resultados reforçam a importância do monitoramento de indicadores fisiológicos, metabólicos e perceptuais para a compreensão da regulação do esforço e das demandas termorregulatórias em atividades de longa duração.

Do ponto de vista prático, o acompanhamento das alterações na percepção de esforço e na temperatura da pele pode orientar as estratégias de pacing, hidratação e, principalmente, de recuperação. Além disso, a associação entre maior distância percorrida, maior carga perceptiva e fisiológica destaca a necessidade de abordagens individualizadas de recuperação e acompanhamento pós-esforço em atletas submetidos a esforços de longa duração.

Como limitações, destaca-se a amostra composta exclusivamente por homens militares altamente treinados, o que pode restringir a generalização dos resultados para populações civis, mulheres ou indivíduos com menor nível de treinamento. Além disso, a ausência de controle experimental sobre variáveis como nutrição, sono e estratégias de hidratação individuais durante o evento limita a interpretação de alguns resultados.

Para pesquisas futuras, recomenda-se o aprofundamento na investigação de mecanismos termorregulatórios em diferentes perfis de corredores e ambientes térmicos. A incorporação de tecnologias de monitoramento contínuo da temperatura da pele e de variáveis cardíacas também se mostra promissora para avanços na área do treinamento e da performance em endurance.

Conclui-se, portanto, que a integração de múltiplos marcadores é a melhor abordagem para compreender os desafios termorregulatórios enfrentados durante a corrida de longa duração, contribuindo para otimizar o desempenho e preservar a saúde dos atletas expostos a condições extremas.



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## Apêndice A – Termo de Consentimento Livre e Esclarecido



### CONSENTIMIENTO INFORMADO

**PROYECTO:** “Estudio de los efectos de la actividad física de larga duración en soldados de la Brigada Paracaidista evaluada mediante termografía infrarroja”.

La Facultad de Ciencias de la Actividad Física y del Deporte de la Universidad Politécnica de Madrid (INEF-UPM) y la Brigada Paracaidista van a llevar a cabo un estudio conjunto con el fin de comprobar el efecto de la actividad física de larga duración en la temperatura corporal de los brigadistas. De esta forma, se podrán anticipar los efectos de la fatiga y se podrán establecer en un futuro, por una parte, los medios para retrasarla y, por otra, el momento en que se deba establecer una pausa para la recuperación.

Para ello, al menos 50 miembros voluntarios de la brigada paracaidista de la base Príncipe de Madrid, efectuarán tres tramos de dos horas de ejercicio continuo (corriendo y/o andando) a un ritmo en el que el brigadista piense que va a realizar el mayor número de metros al finalizar las 6 horas de ejercicio.

Antes, durante, inmediatamente después de las 6 horas de actividad física y a las 24 horas y 48 horas de recuperación, se realizará el registro de información personal y de entrenamiento, variables antropométricas (masa corporal, talla, IMC y pliegues cutáneos de tríceps y gemelos), el ritmo de la prueba en los diferentes tramos, un salto con contra-movimiento en una plataforma de fuerzas, la presión arterial y frecuencia cardíaca, la temperatura timpánica y temperatura cutánea por medio de termografía infrarroja, varias escalas perceptivas (de nivel de recuperación, esfuerzo, dolor, sensación térmica, preferencia térmica, sensación de sed, y humedad de la piel), un examen de orina antes y después de la prueba. El registro de imágenes termográficas y resto de las pruebas realizadas son completamente inocuas, rápidos, no invasivos y no suponen ningún riesgo para los participantes.

Los resultados individuales serán confidenciales y serán proporcionados únicamente a los brigadistas, los responsables de la brigada recibirán los resultados individuales codificados, así como los resultados generales de todos los participantes, y se generará un informe que será presentado después del análisis de los mismos.

La realización de la prueba es voluntaria. Si en cualquier momento durante la realización de la prueba por cualquier motivo cambiara de opinión, puede decidir no seguir realizándola.

Agradeciendo de antemano su colaboración. Para cualquier consulta no dude ponerse en contacto con el responsable del proyecto (Profesor Dr. Manuel Sillero Quintana: )

Yo D/D<sup>a</sup> \_\_\_\_\_, con DNI \_\_\_\_\_, habiendo sido informado previamente, participaré voluntariamente la toma de datos termográficos para el proyecto “Estudio de los efectos de la actividad física de larga duración en soldados de la Brigada Paracaidista evaluada mediante termografía infrarroja”, que va a ser realizado por el equipo liderado por el Prof. Dr. Manuel Sillero Quintana. En el presente proyecto se respetará la normativa vigente referente al tratamiento autorizado de datos (Ley Orgánica 3/2018, de 5 de diciembre, de Protección de Datos Personales y garantía de los derechos digitales), siendo los resultados de estos confidenciales.

He leído, comprendo la información presentada y permito que se traten los datos con la única finalidad científica y de difusión entre los mandos de la Ejército Español, en tanto se respeten la confidencialidad y el anonimato de estos, y el tratamiento se efectúe previo procedimiento de disociación, de forma que no puedan ser expuestos en relación con mi persona.

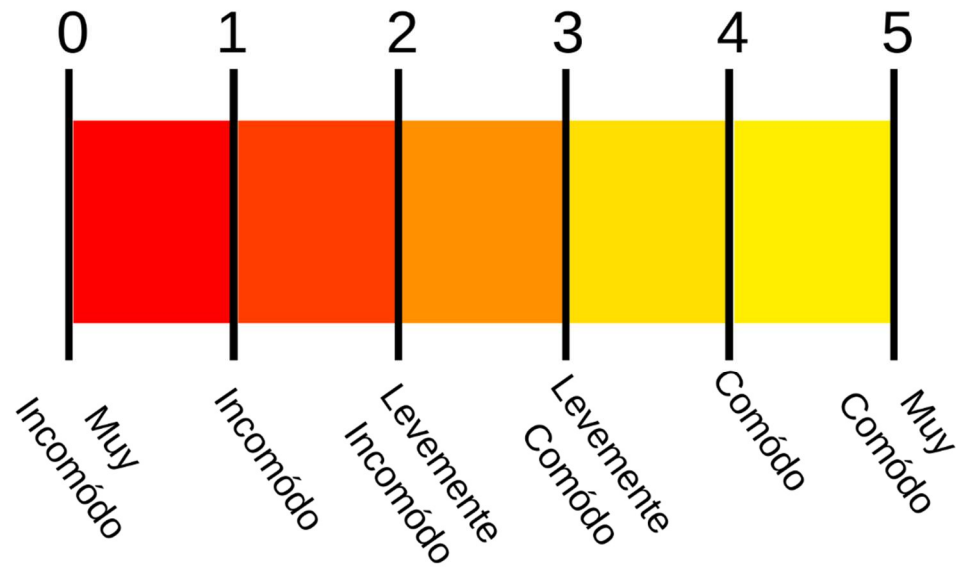
Firmado:

Autorizado:

## Apêndice B – Escala de Conforto Térmico



### ESCALA DE COMODIDAD TÉRMICA



OLESEN & BRAGER (2004); VARGAS et al (2018)



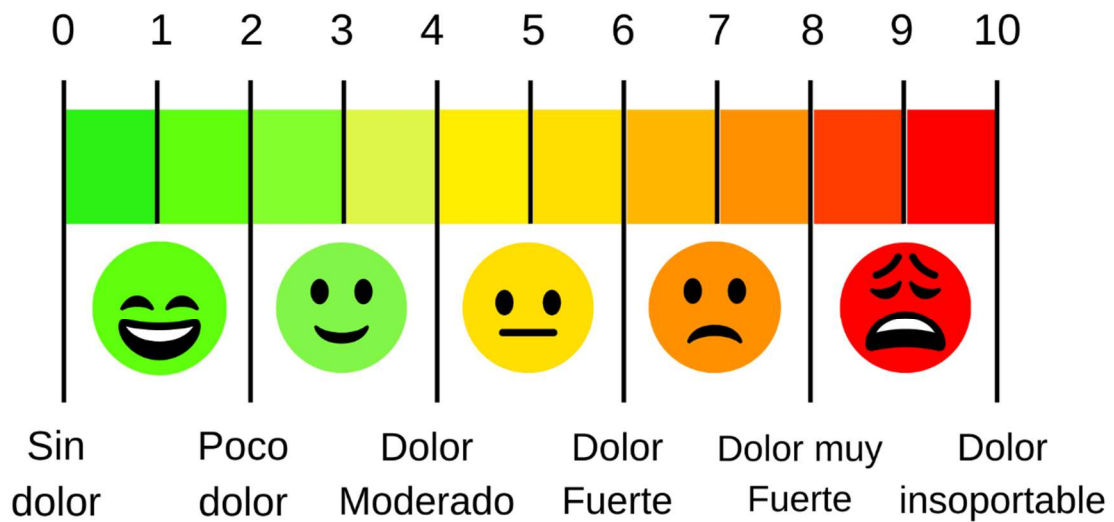
## Apêndice C – Escala de Percepção de Dor



### PERCEPCIÓN DEL DOLOR



¿Cómo califica su dolor?

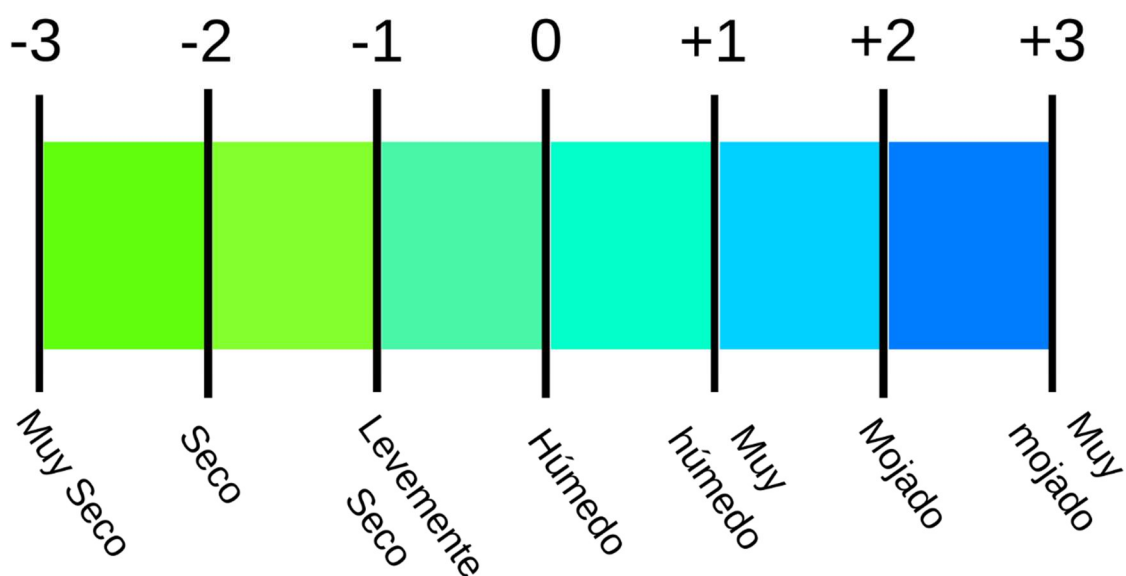


BENNET (2001); GIFT (1989); VILLANUEVA et al (2018)

## Apêndice D – Escala de Percepção de Umidade da Pele



### PERCEPCIÓN DE HUMEDAD EN LA PIEL

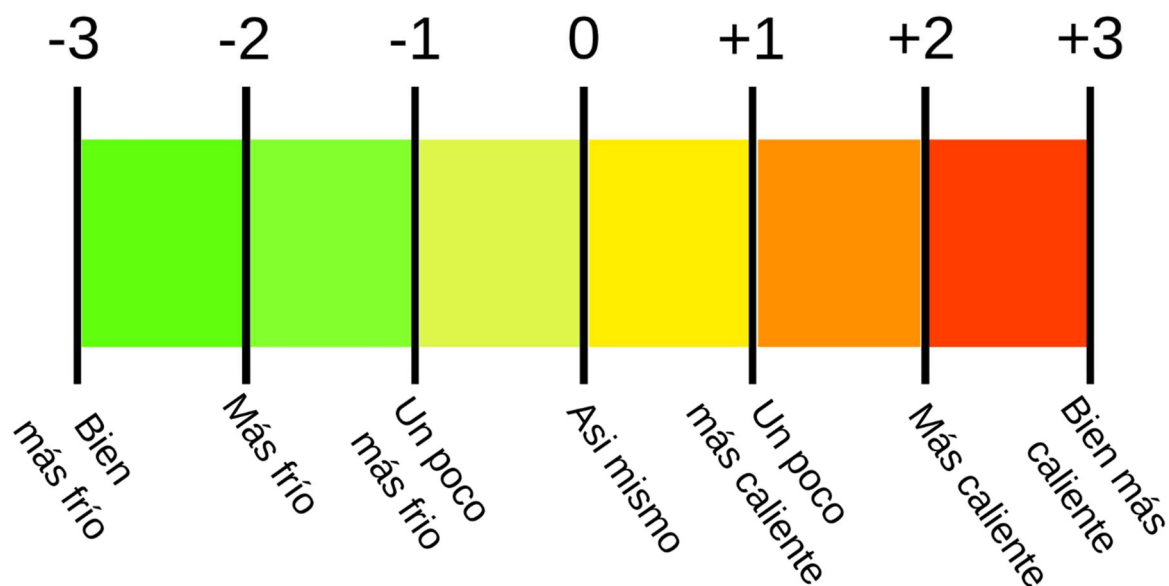


OLESEN & BRAGER (2004); VARGAS et al (2018)

## Apêndice E – Escala de Preferência Térmica



### ESCALA DE PREFERENCIA TÉRMICA



GAGGE, STOLWIJK, HARDY (1967); GAGGE, STOLWIJK, SALTIN (1969); ISO 10551 (2019)

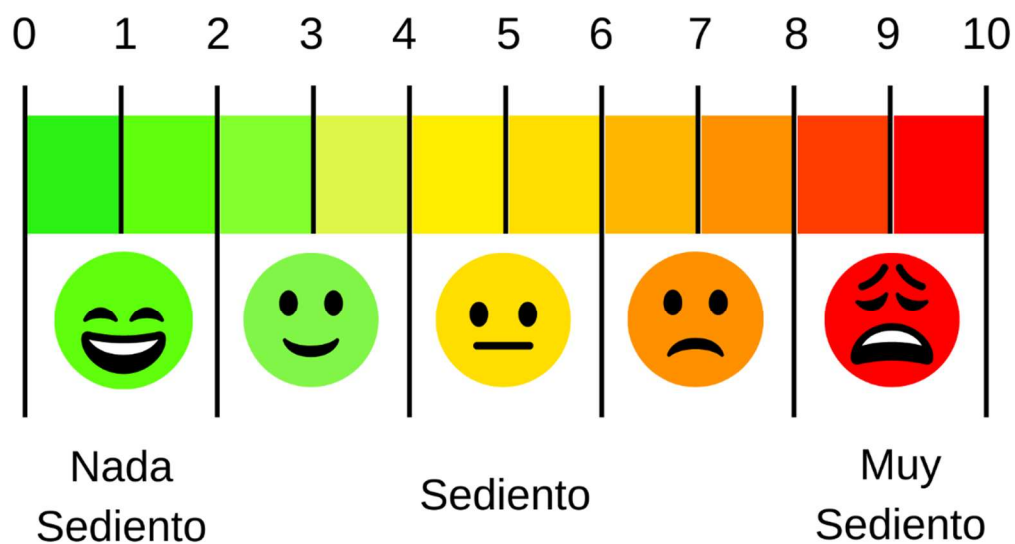
## Apêndice F – Escala de Percepção de Sede



### PERCEPCIÓN DE LA SED



¿Como te sientes ahora?

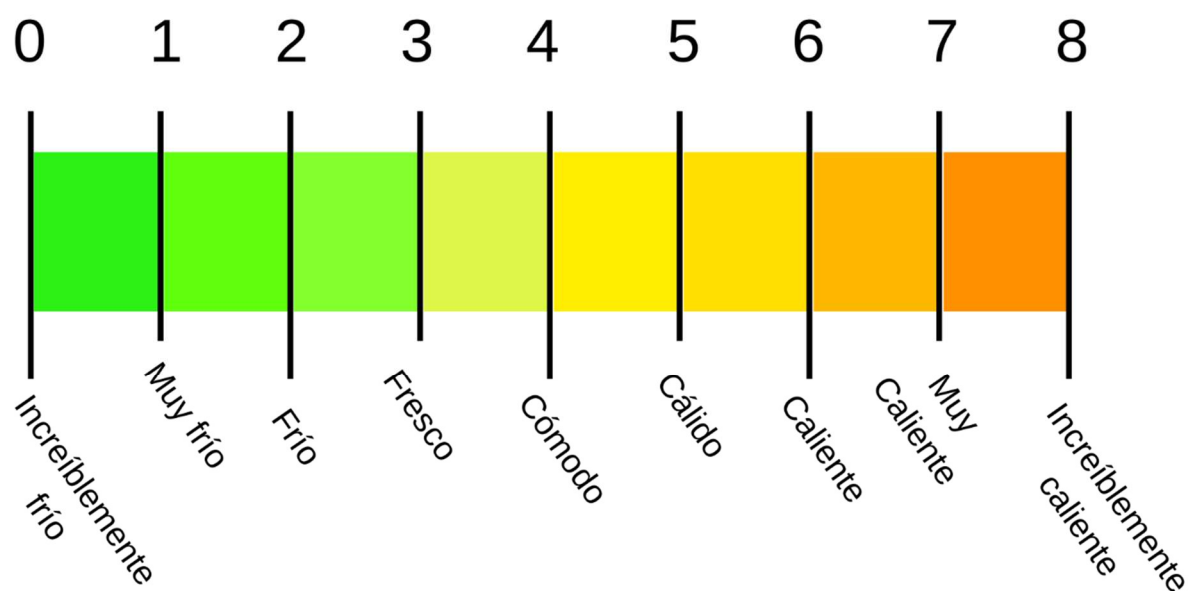


ENGELL et al (1987); GREENLEAF (1992)

## Apêndice G – Escala de Sensação Térmica



### ESCALA DE SENSACIÓN TÉRMICA



YOUNG et al (1987)

## Apêndice H – Escala de Percepção do Esforço



**“Efectos de la actividad física de larga duración en soldados de la Brigada Paracaidista evaluada mediante termografía infrarroja”**

### **ESCALA DE PERCEPCIÓN DEL ESFUERZO**

<b>0</b>	<b><i>Reposo</i></b>
<b>1</b>	<b><i>Muy, muy fácil</i></b>
<b>2</b>	<b><i>Fácil</i></b>
<b>3</b>	<b><i>Moderado</i></b>
<b>4</b>	<b><i>Algo fuerte</i></b>
<b>5</b>	<b><i>Fuerte</i></b>
<b>6</b>	<b>-</b>
<b>7</b>	<b><i>Muy fuerte</i></b>
<b>8</b>	<b>-</b>
<b>9</b>	<b>-</b>
<b>10</b>	<b><i>Máximo esfuerzo</i></b>

**BORG (1970; 1982); FOSTER et al (2001)**

## Apêndice I – Escala Subjetiva de Recuperação (SRS)



### ESCALA DE *RECUPERACIÓN*

<b>0</b>	<b><i>Muy mal recuperado</i></b>
<b>1</b>	
<b>2</b>	<b><i>Muy poco recuperado</i></b>
<b>3</b>	
<b>4</b>	<b><i>Algo recuperado</i></b>
<b>5</b>	<b><i>Adecuadamente recuperado</i></b>
<b>6</b>	<b><i>Moderadamente recuperado</i></b>
<b>7</b>	
<b>8</b>	<b><i>Bien recuperado</i></b>
<b>9</b>	
<b>10</b>	<b><i>Muy bien recuperado</i></b>

LAURENT et al (2011); KENTTÄ & HASSMÉN (1998)

## Apêndice J – Instruções, Questionários e Folhas de Registros de Dados



### INSTRUCCIONES PARA LOS VOLUNTARIOS

**PROYECTO:** "Estudio de los efectos de la actividad física de larga duración en soldados de la Brigada Paracaidista evaluada mediante termografía infrarroja".

Os agradecemos enormemente vuestra colaboración en este proyecto que lleva a cabo de manera conjunta la Brigada Paracaidista y la Facultad de Ciencias de la Actividad Física y del Deporte (INEF) de la Universidad Politécnica de Madrid (UPM).

En la jornada de formación vamos a recoger los consentimientos informados, a practicar el protocolo de realización de los test y realizaremos una toma de datos iniciales que permitan categorizar la muestra y excluir aquellos voluntarios que puedan presentar alguna característica influyente en la toma de datos.

Hoy os daremos un número de orden que será nuestro vuestro código para los días siguientes.

La prueba se debe realizar en unas condiciones estandarizadas. Por ello, os pedimos que:

#### EL DÍA ANTES DE LA PRUEBA:

- 1) No realicéis una actividad de máxima intensidad durante el día.
- 2) No ingiráis alcohol la noche anterior.
- 3) No os depiléis, ni os deis un masaje.
- 4) Tratad de dormir 8 horas.

#### EL DÍA DE LA PRUEBA:

- 1) Realizad un desayuno normal, sin ingerir alcohol.
- 2) No toméis ningún tipo de fluido energético, principalmente aquellos que contengan cafeína.
- 3) No os pongáis ningún tipo de crema en la piel.
- 4) No vengáis a la base corriendo o en bicicleta.

Con el fin de facilitar la toma de datos, la prueba se realizará de manera escalonada, en forma de "contrarreloj", en la pista de atletismo de la base con salidas cada dos minutos, siguiendo el orden que os demos en la jornada informativa. La prueba (3 tramos de 2 horas de carrera/marcha continua con 2 descansos de 15 min) comenzará a las 09:00 horas del miércoles **XX** de Octubre de 2022. Por lo tanto, el brigadista número 22 debería de llegar a la pista un poco antes de las 9:44. Se realizarán dos tomas de datos siguiendo el siguiente esquema:



**LOS DOS DÍAS DESPUES DE LA PRUEBA:** Se realizarán dos tomas de datos. Una a las 24 horas y otra a las 48 horas después de la prueba principal. En ellas se realizará una única toma de datos, que comenzará a las 9:00 de la mañana y que, de nuevo, se hará de manera escalonada, cada dos minutos siguiendo el mismo número de orden. La duración de esta toma de datos será solo de unos 10 minutos.



(continuação)



"Efectos de la actividad física de larga duración en soldados de la Brigada Paracaidista evaluada mediante termografía infrarroja"

## Cuestionario de Información Personal

Nombre y apellidos: \_\_\_\_\_

Fecha de Nacimiento: \_\_\_\_ / \_\_\_\_ / \_\_\_\_ Código: \_\_\_\_\_

Correo Electrónico: \_\_\_\_\_

Deporte practicado (a parte de la instrucción): \_\_\_\_\_

HISTORIAL DE ENTRENAMIENTO (SIN INCLUIR LA INSTRUCCIÓN) Y DE LESIONES	
Años de práctica deportiva: _____ años Sesiones semanales (promedio): _____	
¿Has tenido alguna lesión en los últimos 90 días que te impidió entrenar? <input type="checkbox"/> NO <input type="checkbox"/> SÍ	
¿Cual? _____ ¿Utilizas algún medicamento? <input type="checkbox"/> NO <input type="checkbox"/> SÍ	
SI COMPITES EN LA ACTUALIDAD CARRERAS ¿En que distancias?:	
<input type="checkbox"/> No compito en carrera <input type="checkbox"/> 5 a 10 km <input type="checkbox"/> 11 a 21 km <input type="checkbox"/> 22 a 42 km <input type="checkbox"/> Más que 42	
¿Has competido en alguna prueba de más de 3 horas?: <input type="checkbox"/> SI <input type="checkbox"/> NO ¿Cuántas aprox.? _____	
Entrenamiento en los últimos 3 meses:	Volumen semanal (Si se conoce)
Entrenamientos por semana (promedio): _____	TOTAL (promedio): _____ km
Duración de la sesión (promedio): _____ minutos	
OBSERVACIONES:	

ENTRENAMIENTOS DE INSTRUCCIÓN en los últimos 3 meses:		
DISTANCIA (APROX)	DURACIÓN	¿CUANTOS?
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ESTRATEGIAS PARA LA PRUEBA CONTRA RELOJ (3 tramos de 2 horas)	
PREDICCIÓN DE RENDIMIENTO: _____ km	PUESTO (del 1 al 50) _____
Forma de realizar la prueba: <input type="checkbox"/> Carrera continua <input type="checkbox"/> Correr y andar <input type="checkbox"/> Andar <input type="checkbox"/> No lo sé	
Estrategia de prueba (3 tramos): <input type="checkbox"/> Todos igual <input type="checkbox"/> De menos a más <input type="checkbox"/> De más a menos <input type="checkbox"/> No lo sé	

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## HOJA DE REGISTRO DE DATOS SALTOS



"Efectos de la actividad física de larga duración en soldados de la Brigada Paracaidista evaluada mediante termografía infrarroja"

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# HOJA DE REGISTRO DE DATOS SENSACIÓN TÉRMICA, SED, COMODIDA Y HUMEDAD DE LA PIEL



"Efectos de la actividad física de larga duración en soldados de la Brigada Paracaidista evaluada mediante termografía infrarroja"

	Antes de la prueba				Durante la Prueba												Después de la prueba								TRAG 24h				TRAG 48h			
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## HOJA DE REGISTRO DE DATOS TEMPERATURA TIMPÁNICA



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## HOJA DE REGISTRO DE DATOS TERMOGRAMAS



"Efectos de la actividad física de larga duración en soldados de la Brigada Paracaidista evaluada mediante termografía infrarroja"

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## HOJA DE REGISTRO DE DATOS PESO Y TALLA



"Efectos de la actividad física de larga duración en soldados de la Brigada Paracaidista evaluada mediante termografía infrarroja"

	Antes de la prueba		Durante la Prueba						Después de la prueba				TRAS 24h		TRAS 48h	
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# HOJA DE REGISTRO DE DATOS ÁGUA, BARRITAS, BANANA Y CHOCOLATE



"Efectos de la actividad física de larga duración en soldados de la Brigada Paracaidista evaluada mediante termografía infrarroja"

	2 horas				4 horas				6 horas			
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# HOJA DE REGISTRO DE DATOS PRESIÓN ARTERIAL Y FRECUENCIA CARDÍACA



"Efectos de la actividad física de larga duración en soldados de la Brigada Paracaidista evaluada mediante termografía infrarroja"

	Antes de la prueba			Durante la Prueba						Después de la prueba						TRAS 24h			TRAS 48h		
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## HOJA DE REGISTRO DE DATOS RECUPERACIÓN, ESFUERZO Y DOLOR



"Efectos de la actividad física de larga duración en soldados de la Brigada Paracaidista evaluada mediante termografía infrarroja"

	Antes de la prueba			Durante la Prueba												Después de la prueba						TRAS 24h			TRAS 48h		
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## Influence of body position on skin temperature, heart rate, and blood pressure in active men

Victor Hugo Pereira Franco<sup>a,b</sup>, Aldo A. Vasquez-Bonilla<sup>c,\*</sup>, Manuel Sillero-Quintana<sup>d</sup>

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<sup>b</sup> Faculty of Physical Education and Sports, Federal University of Juiz de Fora, Juiz de Fora, Brazil

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### ARTICLE INFO

#### Keywords

Thermography  
Body position  
Temperature  
And environmental physiology

### ABSTRACT

The use of thermography to measure skin temperature (Tsk) is typically assessed in a standing position; however, the differences of Tsk in different body positions have not been adequately studied. This study aimed to analyze the influence of body position (sitting, standing, and supine) on Tsk. Twenty-nine trained men (age  $23.52 \pm 0.34$  years) spent 10 minutes in each of the three positions in random order. During these postures, the heart rate (HR) response and systolic and diastolic blood pressure were measured as influential cardiovascular variables. Tsk was measured in the trapezius, shoulder, chest, biceps, costal, elbow, abdomen, and forearm. Covariance analysis (ANCOVA), intraclass correlation (ICC), typical error, and effect size (ES) were applied. When comparing the three positions, greater variations in Tsk were observed in the shoulder ( $0.74-1.31\%$ ), biceps ( $-0.36-1.33\%$ ), elbow ( $0.46-1.20\%$ ) and forearm ( $0.58-1.41\%$ ). HR varied significantly between the different positions ( $p < 0.05$ ), influencing Tsk in the chest ( $ES = 0.71$ ), the biceps ( $ES = 0.56$ ) and abdominal regions ( $ES = 0.91$ ) in the sitting position compared to the supine position, and in the abdominal region ( $ES = 1.12$ ) in the standing position compared to the supine position. The reliability of the measurement was excellent in the chest ( $ICC = 0.91$ ), costal ( $ICC = 0.91$ ), and abdominal ( $ICC = 0.89$ ) regions. Although many studies traditionally measure Tsk in a standing position, the results of this study support that the Tsk distribution varies with body position, and this factor should be considered in any study using thermography.

### 1. Introduction

Skin is the largest organ in our body and has crucial functions as controlling the loss of water and protecting the body against mechanical, chemical, or biological attacks (Menon and Kligman, 2009), and collaborating to keep body temperature through a very complex thermoregulation process (Romanovsky, 2014). The controlling factor for skin temperature (Tsk) is the blood flow rate (Charkoudian, 2003), being the control of the body temperature carried out mainly by the blood vessels and nerves located in the skin. The absolute Tsk varies depending on the environmental temperature, the exposure time, and the part of the body to be assessed (Namkoong et al., 2015). Under cold conditions, the body promotes vasoconstriction to maintain heat in internal organs, and under hot conditions, there is an active dilation of the small vessels of the skin that facilitates the removal of excess heat (Ratovoson et al.,

2013).

It has been well known since many years ago that changes in body position can modify hemodynamic behavior in the human body (Jones and Dean, 2004). Gravitational stress, or the compression force that constantly affects the structure of the human body, is a fundamental variable capable of affecting circulatory homeostasis. In addition to this, the variation of posture has been related with variations of the vagal activity. Nepal and Paudel (2012) found significant decreases in HR variability parameters, reflecting vagal activity and reciprocal increase in sympathetic activity in standing as compared to sitting and supine, which generated significantly higher HR values in standing compared to sitting and supine position. In this study, the systolic and diastolic blood pressure was not significantly modified. However, little is known about how regional distributions of blood flow are affected by changes in body position and how such changes influence human Tsk (Ratovoson et al.,

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## **Anexo B - Aprovação pelo Comitê de Ética em Pesquisa da Universidade Federal de Juiz de Fora**



### **PARECER CONSUBSTANCIADO DO CEP**

#### **DADOS DO PROJETO DE PESQUISA**

**Título da Pesquisa:** Periodização e rendimento de maratonistas e ultramaratonistas.

**Pesquisador:** VICTOR HUGO PEREIRA FRANCO

**Área Temática:**

**Versão:** 2

**CAAE:** 03353118.9.0000.5147

**Instituição Proponente:** Faculdade de Educação Física

**Patrocinador Principal:** Financiamento Próprio

#### **DADOS DO PARECER**

**Número do Parecer:** 3.085.114

#### **Apresentação do Projeto:**

Trata-se de um estudo descritivo tendo corredores de rua ou de montanha, principalmente ultramaratonistas, como população amostral a ser estudada. Serão avaliados 50 atletas/prova, de ambos os sexos, com idade acima de 18 anos. Por meio de contato pessoal realizado pelo pesquisador, os voluntários que apresentarem as características da amostra pretendida serão convidados a participar da pesquisa. Nesse contato inicial serão informados ao voluntário todos os procedimentos, riscos e benefícios. Caso o indivíduo aceite participar da pesquisa, os questionários e procedimentos serão aplicados pelo pesquisador (será o mesmo em todas as provas), sendo essa coleta de dados realizada durante a retirada de kits em uma sala sem ruídos e possíveis distrações (fornecida pela organização) em algumas das principais Maratonas e Ultramaratonas do Brasil (Ultramaratona BR135+ no mês de janeiro; Maratona do Rio de Janeiro e a Ultramaratona dos Anjos Internacional no mês de junho; Ultramaratona "Caminhos de Rosa" no mês de setembro; Ultra 24h Rio de Janeiro no mês de outubro; e Ultra Night Run 12h Vila Velha/ES no mês de dezembro) nos anos de 2019 e 2020, totalizando 12 provas. Por ser uma pesquisa descritiva haverá apenas uma abordagem aos voluntários. Nessa abordagem serão esclarecidos todos os procedimentos do projeto ao voluntário:

- (1) aplicação de um questionário geral (durante a retirada de kits das provas);
- (2) aplicação dos questionários de Motivação e "Flow Feeling" (durante a retirada de kits das provas);

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(3) Percepção de Esforço (a cada 30 a 60 minutos durante a realização da prova);  
(4) Avaliação termográfica de membros inferiores e superiores (vistas frontal, lateral direita e posterior) será realizada 30 minutos antes da largada, a cada 30 minutos de prova e 30 minutos após a conclusão da prova, sendo coletada dentro da pista de prova, não interferindo na performance do atleta, uma vez que é necessário aproximadamente 1 minuto, em média, para a coleta das imagens termográficas. Apresentação do projeto está clara, detalhada de forma objetiva, descreve as bases científicas que justificam o estudo, estando de acordo com as atribuições definidas na Resolução CNS 466/12 de 2012, item III.

#### Objetivo da Pesquisa:

##### Objetivo Primário:

Analisar a relação das variáveis de treinamento e dos modelos de periodização com o resultado alcançado por maratonistas e ultramaratonistas.

##### Objetivo Secundário:

- Avaliar as variáveis do treinamento (volume, intensidade, experiência, tempo de preparação) que mais se relacionam com a performance nas Maratonas e Ultramaratonas;
- Verificar as análises termográficas e de percepção de esforço durante a maratona ou ultramaratona;
- Conhecer os aspectos psicológicos envolvidos na preparação e competição (Motivação e flow feeling);
- Analisar a estratégia de pacing utilizada durante a prova. • Investigar a incidência de lesões mais comuns nesses atletas;
- Analisar a realização dos treinamentos complementares na preparação dos maratonistas e ultramaratonistas.

Os Objetivos da pesquisa estão claros bem delineados, apresenta clareza e compatibilidade com a proposta, tendo adequação da metodologia aos objetivos pretendido, de acordo com as atribuições definidas na Norma Operacional CNS 001 de 2013, item 3.4.1 - 4.

#### Avaliação dos Riscos e Benefícios:

Os riscos deste estudo são mínimos, inerentes a possibilidade de a possibilidade de lesão por trauma, portanto, em função das características da amostra (ultramaratonistas experientes e bem treinados), não se espera a ocorrência de agravos na

saúde associados à participação nas provas de maratonas e ultramaratonas em que a pesquisa acontecerá. Durante a realização dos procedimentos, qualquer intercorrência detectada que possa colocar em risco a saúde dos voluntários, interromperá a realização dos mesmos. Adicionalmente,

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assistências imediatas e integrais aos prováveis riscos e danos da pesquisa serão asseguradas pelo pesquisador e instituições envolvidas. Explicitação dos possíveis desconfortos e riscos decorrentes da participação, assim como providências e cautelas a serem empregadas para evitar e/ou reduzir efeitos e condições adversas que possam causar dano, será incluída no protocolo de instrução do participante e reforçada quando necessário. Como benefício aos voluntários da pesquisa terão do estudo, o recebimento de um relatório em que constará o resultado de todas as avaliações realizadas por ele (análise das variáveis de treinamento, variação termográfica e escala de percepção de esforço). E ainda, os achados dessa pesquisa ampliarão os conhecimentos dos treinadores e demais profissionais ligados ao treinamento de ultramaratonistas, auxiliando na promoção da performance de ultramaratonistas. Riscos e benefícios descritos em conformidade com a natureza e propósitos da pesquisa. O risco que o projeto apresenta é caracterizado como risco mínimo e benefícios esperados estão adequadamente descritos. A avaliação dos Riscos e Benefícios está de acordo com as atribuições definidas na Resolução CNS 466/12 de 2012, itens III; III.2 e V.

#### Comentários e Considerações sobre a Pesquisa:

O projeto está bem estruturado, delineado e fundamentado, sustenta os objetivos do estudo em sua metodologia de forma clara e objetiva, e se apresenta em consonância com os princípios éticos norteadores da ética na pesquisa científica envolvendo seres humanos elencados na resolução 466/12 do CNS e com a Norma Operacional Nº 001/2013 CNS.

#### Considerações sobre os Termos de apresentação obrigatória:

O protocolo de pesquisa está em configuração adequada, apresenta FOLHA DE ROSTO devidamente preenchida, com o título em português, identifica o patrocinador pela pesquisa, estando de acordo com as atribuições definidas na Norma Operacional CNS 001 de 2013 item 3.3 letra a; e 3.4.1 item 16. Apresenta o TERMO DE CONSENTIMENTO LIVRE ESCLARECIDO em linguagem clara para compreensão dos participantes, apresenta justificativa e objetivo, campo para identificação do participante, descreve de forma suficiente os procedimentos, informa que uma das vias do TCLE será entregue aos participantes, assegura a liberdade do participante recusar ou retirar o consentimento sem penalidades, garante sigilo e anonimato, explicita riscos e desconfortos esperados, indenização diante de eventuais danos decorrentes da pesquisa, contato do pesquisador e do CEP e informa que os dados da pesquisa ficarão arquivados com o pesquisador pelo período de cinco anos, de acordo com as atribuições definidas na Resolução CNS 466 de 2012, itens: IV letra b; IV.3 letras a, b, d, e, f, g e h; IV. 5 letra d e XI.2 letra f. Apresenta o INSTRUMENTO DE COLETA DE DADOS de forma pertinente aos objetivos delineados e preserva os

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participantes da pesquisa. O Pesquisador apresenta titulação e experiência compatível com o projeto de pesquisa, estando de acordo com as atribuições definidas no Manual Operacional para CPEs.

#### Conclusões ou Pendências e Lista de Inadequações:

Diante do exposto, o projeto está aprovado, pois está de acordo com os princípios éticos norteadores da ética em pesquisa estabelecido na Res. 466/12 CNS e com a Norma Operacional Nº 001/2013 CNS. Data prevista para o término da pesquisa: dezembro de 2022.

#### Considerações Finais a critério do CEP:

Diante do exposto, o Comitê de Ética em Pesquisa CEP/UFJF, de acordo com as atribuições definidas na Res. CNS 466/12 e com a Norma Operacional Nº 001/2013 CNS, manifesta-se pela APROVAÇÃO do protocolo de pesquisa proposto. Vale lembrar ao pesquisador responsável pelo projeto, o compromisso de envio ao CEP de relatórios parciais e/ou total de sua pesquisa informando o andamento da mesma, comunicando também eventos adversos e eventuais modificações no protocolo.

Este parecer foi elaborado baseado nos documentos abaixo relacionados:

Tipo Documento	Arquivo	Postagem	Autor	Situação
Informações Básicas do Projeto	PB_INFORMAÇÕES_BÁSICAS_DO_PROJETO_1250431.pdf	13/12/2018 16:16:51		Aceito
Projeto Detalhado / Brochura Investigador	projetocep.docx	13/12/2018 16:16:11	VICTOR HUGO PEREIRA FRANCO	Aceito
TCLE / Termos de Assentimento / Justificativa de Ausência	tcle_victor_ultra.docx	21/11/2018 21:35:32	VICTOR HUGO PEREIRA FRANCO	Aceito
Outros	CADERNO_DE_COLETA.docx	21/11/2018 21:34:17	VICTOR HUGO PEREIRA FRANCO	Aceito
Folha de Rosto	folhaDeRosto.pdf	21/11/2018 21:32:45	VICTOR HUGO PEREIRA FRANCO	Aceito

#### Situação do Parecer:

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(continuação)



Continuação do Parecer: 3.085.114

Aprovado

Necessita Apreciação da CONEP:

Não

JUIZ DE FORA, 14 de Dezembro de 2018

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Assinado por:  
Jubel Barreto  
(Coordenador(a))

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