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

Juiz de Fora
2025

VICTOR HUGO PEREIRA FRANCO

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Tese de Doutorado apresentada ao Programa de Pós-Graduação em Educação Física da Universidade Federal de Juiz de Fora, como requisito parcial à obtenção do título de Doutor em Educação Física. Área de concentração: Exercício e Esporte.

Orientador: Prof. Dr. Jorge Roberto Perrout de Lima

Coorientador: Prof. Dr. Manuel Sillero Quintana

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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 dois 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 ± 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≤0,001 para todas as comparações). A distância total apresentou correlação positiva com a temperatura da coxa direita e esquerda no POST6h (p≤0,036 para todas as comparações) e a percepção do esforço no POST4h e no POST6h (p≤0,008 para todas as comparações). A temperatura corporal (Body Surface Temperature - BST) no POST4h apresentou correlação inversa com a distância total (p≤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 two 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 ± 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 (PRE24h and PRE1h), during the effort (2h, 4h and 6h), and after the end of the race (POST1h, POST24h, and POST48h). **RESULTS:** Article 1: All groups showed an increased temperature at $POST_{6h}$ vs. PRE [1.9 (0.1; 3.7) °C; p=0.037] and $POST_{2h}$ [2.3 (0.7; 4.0) °C; p=0.002]. For anterior thigh there was a significant difference between PRE and $POST_{2h}$ vs. $POST_{4h}$ and $POST_{6h}$ (p≤0.001 for all comparison). Total distance showed positive correlation between with the temperature of the right and left thigh $POST_{6h}$ (p≤0.036 for all comparison) and RPE at $POST_{4h}$ and $POST_{6h}$ (p≤0.008 for all comparison). Body surface temperature (BST) at $POST_{4h}$ 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.

LISTA DE ILUSTRAÇÕES

LISTA DE TABELAS

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

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

SUMÁRIO

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, exigindo do organismo uma resposta coordenada de vasodilatação cutânea, aumento do débito cardíaco e ativação das glândulas sudoríparas para promover a dissipação do calor (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 performance e maior risco de complicações como desidratação, exaustão térmica e hipertermia. O equilíbrio entre a produção e a perda de calor torna-se, portanto, um fator determinante da performance, da segurança e até da sobrevivência em provas de resistência (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 (temperatura, umidade, vento, radiação solar, chuva) que interagem com a intensidade, a duração do exercício e o estado de aclimatação do atleta (Bouscaren, Millet & Racinais, 2019; Ebi et al., 2021). 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 (Hoffman & Wegelin, 2009; Scheer, 2019).

Durante esse tipo de prova, o corpo humano busca um equilíbrio dinâmico entre a manutenção da temperatura central e o fornecimento adequado de sangue aos músculos ativos. Essa redistribuição do fluxo sanguíneo constitui uma das principais estratégias de termorregulação, permitindo o resfriamento periférico por meio da vasodilatação cutânea e posterior evaporação do suor. Entretanto, à medida que o esforço se prolonga, ocorre uma redução progressiva da perfusão periférica como resposta adaptativa para preservar o fluxo sanguíneo central e a pressão arterial, especialmente sob condições de calor e fadiga metabólica. Esse redirecionamento do fluxo, contudo, impõe maior sobrecarga ao sistema cardiovascular e pode comprometer o aporte de oxigênio aos músculos ativos, contribuindo para a fadiga progressiva (Périard, Eijsvogels & Daanen, 2021).

O comportamento da temperatura da pele reflete diretamente essa dinâmica fisiológica. Em provas prolongadas, observa-se frequentemente uma redução inicial da temperatura cutânea, resultado da priorização do fluxo sanguíneo para os músculos ativos, seguida por elevação nos estágios finais, associada à vasodilatação reativa e ao restabelecimento do equilíbrio térmico após o esforço. Esse padrão é indicativo não apenas da eficiência dos mecanismos de dissipação de calor, mas também do grau de fadiga e da adaptação cardiovascular do atleta (Périard, Eijsvogels & Daanen, 2021).

Com o avanço da prova e o acúmulo de fadiga, há tendência de redução do ritmo e da produção metabólica, o que altera a dinâmica da termorregulação. A queda no ritmo reduz a produção de calor, mas a manutenção da vasodilatação cutânea pode levar à elevação da temperatura superficial nos estágios finais. Esse comportamento reforça que a temperatura da pele reflete não apenas o estresse térmico externo, mas também o estado de fadiga e o controle autonômico do atleta.

Além das respostas fisiológicas, o componente perceptual desempenha papel central no controle da intensidade do exercício. A percepção de esforço, o desconforto térmico, a sede e a dor são respostas integradas que resultam da interação entre sinais periféricos (temperatura, metabólitos, tensão muscular) e centrais (cérebro, sistema nervoso autônomo). Essas percepções atuam como mecanismos de autorregulação do desempenho, influenciando o ritmo e a tolerância ao esforço em contextos de endurance (Borg, 1982; Costa et al., 2019; Kenttä & Hassmén, 1998).

A integração entre marcadores fisiológicos e perceptuais fornece uma visão abrangente sobre o estresse térmico e o estado de fadiga do atleta. Medidas como temperatura da pele, frequência cardíaca, pressão arterial, massa corporal e análise urinária, associadas a escalas perceptivas de sede, conforto térmico e esforço, permitem uma compreensão mais precisa do equilíbrio entre carga externa e carga interna. Em condições de campo, especialmente em corridas de rua ou eventos militares, essas medidas têm alto valor aplicado, por serem de baixo custo, fácil mensuração e alta sensibilidade às mudanças no estado fisiológico.

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, assim como ainda são raras as investigações que avaliam simultaneamente essas variáveis em diferentes perfis de corredores e em múltiplos momentos do processo de recuperação. 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 comparações e limita a formulação de recomendações práticas (Chudecka & Lubkowska, 2015).

Diante desse panorama, esta tese destaca-se pela abordagem inovadora e holística, integrando variáveis fisiológicas, metabólicas e perceptuais em condições reais de campo, com o uso de termografia infravermelha para monitoramento térmico durante e após uma corrida de longa duração. Nesse contexto, surge a necessidade de compreender como diferentes perfis de desempenho (sub-maratonistas, maratonistas e ultramaratonistas) respondem ao mesmo estímulo prolongado. Hipotetiza-se que atletas com maior volume percorrido apresentem maior estresse térmico e cardiovascular, além de recuperação mais lenta de parâmetros fisiológicos e perceptuais.

Para tanto, 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, podendo embasar o desenvolvimento de estratégias mais eficazes de ritmo, hidratação e recuperação individualizada, com implicações para o treinamento, a prevenção de distúrbios térmicos e a segurança de atletas expostos a ambientes severos.

Assim, o objetivo geral desta tese foi analisar e comparar as respostas cardiovasculares, metabólicas e perceptuais em corredores masculinos treinados antes, durante e após uma corrida contínua de 6 horas, com ênfase na termorregulação e no comportamento da temperatura da pele ao longo do esforço e da recuperação.

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

Abstract

Background: Despite the increase in the number of ultra-distance runners, there are few studies that analyze thermal measurements in these runners. **Aims:** Assess changes in body surface and 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), body surface and thigh skin temperature over the running. **Methods:** This study was conducted in collaboration with the Paratroopers Military Base in Madrid, Spain (BRIPAC). Thirty-nine male military soldiers (27.5 ± 6.2 years; 1.8 ± 0.1 m; 76.7 ± 8.9 kg; BMI: 24.6 ± 2.8 kg/m²; running experience: 15.4 ± 8.0 years) completed a 6-hour continuous run. Participants were stratified by distance covered: Ultra Marathon (>44 km, n=12), Marathon (40–44 km, n=15), and Under Marathon (<40 km, n=12). Infrared thermography and RPE were assessed at baseline and every 2 hours. Skin Temperature was measured using a thermographic camera and all thermograms were analyzed using Thermohuman®**.** **Results:** All groups showed an increased temperature at $POST_{6h}$ vs. PRE [1.9 (0.1; 3.7) °C; p=0.037] and $POST_{2h}$ [2.3 (0.7; 4.0) °C; p=0.002]. For Anterior thigh there was a significant difference between PRE and $POST_{2h}$ vs. $POST_{4h}$ and $POST_{6h}$ (p≤0.001 for all comparison). Total distance showed positive correlation between with the temperature of the right and left thigh $POST_{6h}$ (p≤0.036 for all comparison) and RPE at $POST_{4h}$ and $POST_{6h}$ (p≤0.008 for all comparison). Body Surface Temperature (BST) at $POST_{4h}$ showed inverse correlation with total distance (p≤0.001). **Conclusion:** Rating of Perceived Exertion (RPE) at $POST_{4h}$ and post-race, BST post-race, and thigh temperature at $POST_{4h}$ 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; ultramarathon; running; perceived of exertion; athletic 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 performed in extreme heat challenge athletes' thermoregulatory systems, increasing reliance on cutaneous blood flow and sweat production to dissipate internal heat, a physiological demand critical for maintaining 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 infrared thermography (IRT) to deliver objective, real-time physiological feedback without interfering with performance makes it particularly valuable for optimizing athlete management in extreme endurance contexts (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 these critical gaps, the present study aimed to (1) longitudinally assess total body and thigh skin temperature dynamics, and (2) evaluate the temporal correlations of these variables with running distance and RPE before, at 2h, 4h, and after a 6-hour continuous run. A secondary aim was to establish evidence-based recommendations for real-time physiological monitoring protocols to guide pacing strategies and intervention timing during ultra-endurance events. We hypothesized that increasing thermal strain (elevated body and thigh TSk) and higher RPE responses would correlate inversely with running distance.

2. Methods

2.1. Experimental approach

This study was conducted in collaboration with the Paratroopers Military Base in Madrid, Spain (*BRIPAC*), 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 ≥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 ± 4.5 hours/week; 39.2 ± 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)
Age (years)	27.6 ± 6.4	28.4 ± 7.8	26.5 ± 4.0
Height (m)	1.8 ± 0.1	1.8 ± 0.1	1.8 ± 0.0
Body Mass (kg)	74.8 ± 10.2	77.2 ± 5.7	78.6 ± 10.3
BMI (kg/m^2)	24.5 ± 3.2	24.1 ± 1.7	25.5 ± 3.1
Experience (years)	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$_{2h}$ and POST$_{4h}$: At 2-hour and 4-hour intervals during the run; (c) POST$_{6h}$: 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 University in which the data were collected (Protocol No. 3.085.114).

Figure 1. Schematic representation of the experimental protocol and data collection timeline. Assessments were conducted before (PRE), during (POST2h and POST4h), and immediately after the 6-hour run (POST6h). Runner = running period; Thermal camera = data collection.

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, ensuring consistent visualization of four anatomical views. Thermal images were captured from four standardized positions: anterior superior (AS) and posterior superior (PS) used to estimate Body Surface Temperature (BST); and anterior inferior (AI) and posterior inferior (PI) used to assess thigh temperature and contribute to overall BST analysis. 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).

BST (Figure 2) was calculated using the formula derived from Ramanathan (1964):

BST = 0.3 × [chest] + 0.3 × [upper arm] + 0.2 × [thigh] + 0.2 × [calf].

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 2) using the formula:

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

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.

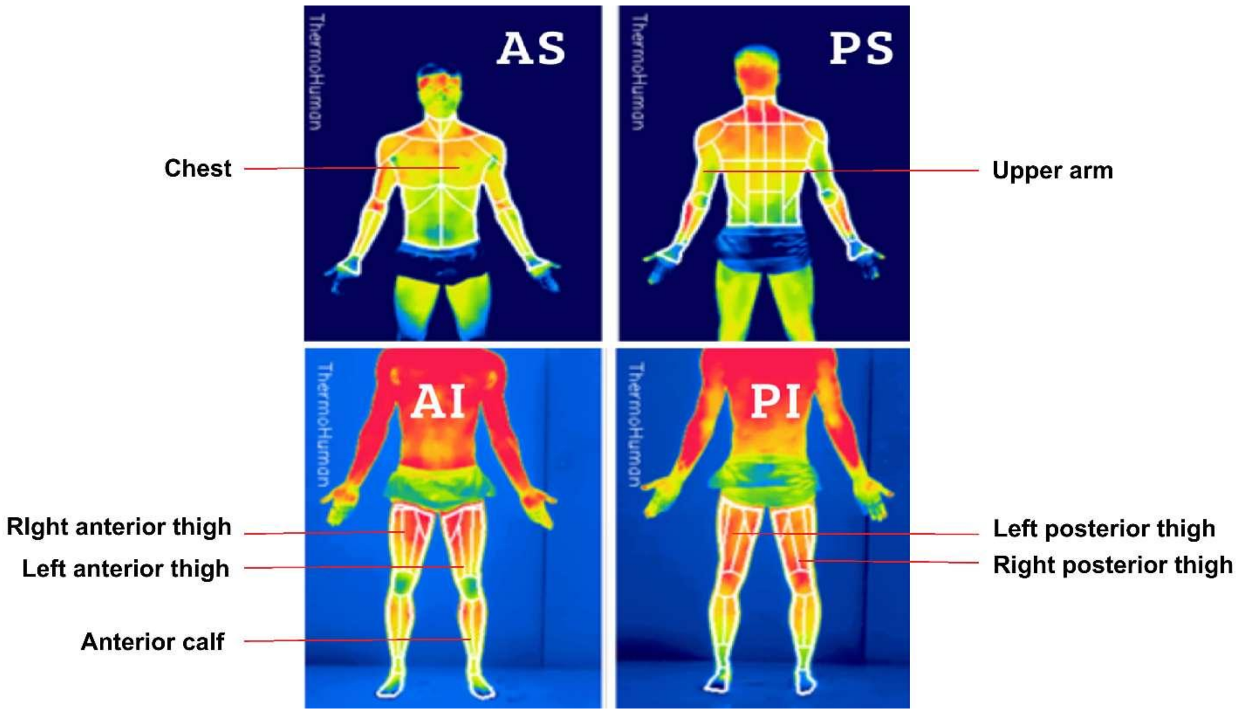

Figure 2. Example of thermographic images analyzed. AS – Anterior superior, PI – posterior inferior, AI – Anterior inferior, PI – posterior inferior. ROI occupied for BST estimative: Chest, Anterior right thigh, Anterior calf, and Posterior upper arm.

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 ($POST_{2h}$, $POST_{4h}$ and $POST_{6h}$).

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 0,1ºC 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	$POST_{2h}$	$POST_{4h}$	$POST_{6h}$
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

Note: Indoor temperature (data collection room), air humidity, and outdoor temperature were monitored using two weather stations.

2.4.5 Performed Distance

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 track, marked by their bib number, containing ad libitum access to water and food (chocolate/cereal bar, banana). Food and fluid intake were individually monitored under the supervision of the research team. This procedure enabled the researchers to record the frequency and approximate volume of intake throughout the run, ensuring adequate monitoring of nutritional and hydration behaviors without disrupting the athletes' natural routines. 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 (ηp^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 ($F_{2,38} = 34.572$, $p < 0.001$, $\eta p^2 = 0.729$). 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 × Time interaction emerged ($F_{2,38}= 2.582$, $p = 0.044$, $\eta p^2= 0.125$). Across all time intervals (PRE, $POST_{2h}$, $POST_{4h}$, $POST_{6h}$). 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 $POST_{6h}$ window compared to earlier intervals ($POST_{2h}$: and $POST_{4h}$: $p < 0.001$ for all comparison), except for the Sub-Marathon group between $POST_{2h}$ and $POST_{4h}$ ($p = 0.055$).

A significant main effect of time was observed for BST ($F_{2,38} = 7.134$, $p = 0.001$, $\eta p^2 = 0.386$). Post-hoc comparisons indicated elevated BST at $POST_{6h}$ compared to PRE (mean difference: +1.9°C, 95% CI [0.1, 3.7], $p = 0.037$), $POST_{2h}$ (mean difference: +2.3°C, 95% CI [0.7, 4.0], $p = 0.002$). For RPE, we observed an isolated effect of moment of measurement ($F_{2,35} = 30.794$, $p \leq 0.001$, $\eta p^2 = 0.638$), where $POST_{6h}$ showed a high PSE vs. $POST_{4h}$ ($p \leq 0.001$) and 2h ($p = 0.009$), and $POST_{4h}$ showed a high PSE vs. $POST_{2h}$ ($p \leq 0.001$). 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, $POST_{2h}$, $POST_{4h}$, $POST_{6h}$ moments of measurement.

	Distance (km)			
Groups	**$POST_{2h}$**	**$POST_{4h}$**	**$POST_{6h}$**	**Total**
Ultra	21.5±3.4^{a*}	15.7±3.7^{b*}	12.3±2.4*	49.4±7.5*
Marathon	18.1±2.4$^{a\#}$	13.2±1.9$^{b\#}$	10.2±1.7$^{b\#}$	41.5±1.3$^{\#}$
Sub-marathon	13.6±3.6	10.7±1.6^{b}	8.5±0.7	32.7±4.5
	Body skin temperature (°C)			
Groups	**PRE ^{c}**	**$POST_{2h}$ ^{c}**	**$POST_{4h}$**	**$POST_{6h}$**
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
	Rating of perceived exertion (a.u.)			
Groups		**$POST_{2h}$ ^{d}**	**$POST_{4h}$ ^{c}**	**$POST_{6h}$**
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

^{a} $p \leq 0.001$ this moment of measurement vs. $POST_{4h}$ and $POST_{6h}$. ^{b} $p \leq 0.001$ this moment of measurement vs. $POST_{6h}$. ^{c} $p \leq 0.037$ this moment of measurement vs. $POST_{6h}$. ^{d} $p \leq 0.001$ this moment of measurement vs. $POST_{4h}$ and $POST_{6h}$. * $p \leq 0.001$ 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, $p < 0.001$, $\eta p^2 = 0.809$). Post-hoc comparisons revealed lower temperatures at Pre-exercise and $POST_{2h}$ compared to $POST_{4h}$ and $POST_{6h}$ ($p < 0.001$ for all comparison). Additionally, the right thigh exhibited a significant decline at $POST_{6h}$ compared to baseline ($p = 0.038$). Similarly, posterior thigh temperature showed a significant main effect of time ($F_{2,38}$ = 27.272, $p < 0.001$, $\eta p^2 = 0.864$). Temperatures at Pre-exercise and $POST_{2h}$ were significantly lower than those at $POST_{4h}$ and $POST_{6h}$ ($p < 0.001$ for all comparison). Finally, at $POST_{6h}$, 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, $POST_{2h}$, $POST_{4h}$, $POST_{6h}$ of the trial, for the anterior and posterior thigh ROI.

	Anterior thigh temperature (°C)							
	PRE		$POST_{2h}$		$POST4_{h}$		$POST6_{h}$	
Side	Right	Left	Right	Left	Right	Left	Right	Left
Ultra	30.4±0.7[a]	30.3±0.7[a]	29.7±0.9[a]	29.7±0.9[a]	31.6±0.6[b]	31.5±0.6	32.1±0.6	32.0±0.6
Marathon	30.3±0.7[a]	30.3±0.8[a]	29.6±1.4[a]	29.6±1.4[a]	30.9±1.2[b]	30.8±1.1	31.3±1.0	31.2±1.0
Sub-marathon	30.0±0 .7	30.0±0.8[a]	29.7±2.0[a]	29.7±1.9[a]	31.1±0.9[b]	31.1±1.0	31.2±0.9	31.2±1.0
	Posterior thigh temperature (°C)							
Ultra	29.8±1.1[a]	29.9±1.0[a]	29.9±1.1[a]	30.1±1.0[a]	31.6±0.8[c]	31.6±0.7[d]	32.1±0.7	32.1±0.6
Marathon	29.9±0.6[a]	29.9±0.6[a]	29.8±1.2[a]	29.7±1.2[a]	31.0±1.3[c]	31.1±1.4[d]	31.3±1.1	31.4±1.1
Sub-marathon	29.4±0.8[a]	29.5±0.8[a]	30.0±1.7[a]	30.0±1.6[a]	31.1±1.0[c]	31.1±1.0[d]	31.3±1.1	31.3±1.0

ROI – region of interest. [a] $p \leq 0.001$ this moment of measurement vs. $POST_{4h}$ and $POST_{6h}$. [b] $p=0.038$ this moment of measurement vs. right anterior thigh at $POST_{6h}$. [c] $p=0.034$ this moment of measurement vs. right posterior thigh at $POST_{6h}$. [d] $p=0.036$ this moment of measurement vs. left posterior thigh $POST_{6h}$.

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 $POST_{6h}$ ($p \leq 0.036$ for all comparison) and RPE at $POST_{4h}$ and $POST_{6h}$ ($p \leq 0.008$ for all comparison). At the last, we found an inverse correlation between the BST at $POST_{4h}$ and the total distance ($p \leq 0.001$). There was not significative correlation between the calf temperature and total distance ($p \geq 0.182$).

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

	BST 4h	ART $POST_{6h}$	ALT $POST_{6h}$	PRT $POST_{6h}$	$PLTPOST_{6h}$	RPE $POST4_{h}$	RPE $POST_{6h}$
Distance	r=-0.551; $p \leq 0.001$	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

Ultra-endurance running represents one of the most demanding physiological models, requiring coordinated adjustments across cardiovascular, metabolic, and thermoregulatory systems to maintain homeostasis during sustained stress (Hermand et al., 2019). Previous studies have described temperature fluctuations in TSk before, during, and after running in shorter or laboratory-based protocols (Gutiérrez-Vargas et al., 2017; Priego-Quesada et al., 2020), but evidence from prolonged continuous events remains limited. 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. In particular, only one small case study with three ultramarathoners documented skin temperature responses in the field (Belinchón-deMiguel et al., 2024), leaving major gaps in our understanding.

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 ± 7.5 km; the MARATHON group covered 41.5 ± 1.3 km; and the SUB-MARATHON group covered 32.7 ± 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 ± 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 ± 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 ± 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°C (±0.6°C), with runners spending 72% of the race time within the core temperature range of 38.0 to 38.9°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°C±0.9°C vs 32.6°C±1.4°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°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°C (HYP) or passive heat exposure in a climatic chamber at 35°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 ± 200 s) compared to the SKIN test (757 ± 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.

As a limitation, wind speed and direction were not recorded during the event, which may have influenced heat dissipation among participants at certain periods of the run.

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 findings reinforce the practical value of continuous thermal and perceptual monitoring during endurance exercise. Tracking body temperature and perceived exertion in real time may assist athletes and coaches in maintaining optimal pacing and identifying early signs of thermal strain. Moreover, these strategies can help prevent heat-related complications such as hyperthermia or heat collapse, particularly in hot and humid conditions.

Finally, the results highlight the importance of implementing individualized cooling strategies, such as skin wetting, ice application, or shade exposure during long-distance events, to enhance thermal comfort, sustain performance, and ensure athlete safety in ultra-endurance competitions.

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.

Abstract

Background: Ultramarathons, often performed under high heat and humidity, impose substantial thermoregulatory and perceptual stress, which can impair performance and increase the risk of heat-related illness. **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 ± 5.7 years) participated in a 6-hour continuous run on a 400-meter track under ambient temperature (28.5 ± 3.2°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). Statistical analyses were conducted using SPSS (v21) with one-way and repeated-measures ANOVA, including Tukey post-hoc tests and Greenhouse-Geisser corrections where applicable; significance was accepted at $p \leq 0.05$. **Results**: Ultrarunners showed greater reductions in body mass, higher heart rate responses, and increased discomfort across multiple perceptual domains. Several perceptual 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; Knettä & 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 design to analyze cardiovascular (heart rate, blood pressure, body mass), metabolic (urine biomarkers), and perceptual (pain, thermal sensation, thirst, and comfort) responses in runners at multiple time points — before, during (every 2 hours), and after (24h and 48h) a 6-hour running event.

The aim 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 Paratroopers Military Base in Madrid, Spain (BRIPAC), employing a longitudinal observational design to examine physiological and perceptual responses during a 6-hour ultramarathon and up to 48 hours post-exercise. Military commanders announced the time-based event, in which participants aimed to cover the maximum distance within six hours on a standardized outdoor circuit. A mandatory pre-event briefing, held 24 hours before the trial, detailed the study's aims, eligibility, procedures, and potential risks, while also providing standardized pre-trial instructions regarding physical activity, substance intake, sleep, and skin preparation to minimize confounding factors.

Following informed consent, athletes received identification numbers for anonymized data tracking. Measurements were collected at baseline, 2, 4, and 6 hours (end of race), and at 24 and 48 hours post-race, allowing the capture of acute and recovery responses. Participants consumed fluids ad libitum under monitoring, and environmental conditions (temperature, humidity, wind speed) were recorded.

Figure 1. Schematic representation of the experimental protocol and data collection timeline. Assessments were conducted before the run (PRE), during exercise (POST2h and POST4h), immediately after completion of the 6-hour run (POST6h), and during recovery at 24 h (POST24h) and 48 h (POST48h) post-exercise. Runner = running period; Sphygmomanometer = data collection.

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 ± 4.5 hours/week; 39.2 ± 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: 40–44 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)**
Age (years)	27.6 ± 6.4	28.4 ± 7.8	26.5 ± 4.0
Height (m)	1.8 ± 0.1	1.8 ± 0.1	1.8 ± 0.0
Body Mass (kg)	74.8 ± 10.2	77.2 ± 5.7	78.6 ± 10.3
BMI (kg/m^2)	24.5 ± 3.2	24.1 ± 1.7	25.5 ± 3.1
Experience (years)	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 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.

The protocol was approved by the University Ethics Committee (Protocol No. 3.085.114).

2.4. Measurements

2.4.1 Anthropometrics

On the day before the event, height was measured with a stadiometer (SECA 213®, Deutschland, ±0.1 cm) following ISAK guidelines by an accredited level 3 anthropometrist to calculate body mass index (BMI). Body mass was recorded using calibrated digital scales (SECA 813, Deutschland, ±0.1 kg) at all measurement time points to assess changes throughout the event and recovery period. Dehydration levels were calculated as the percentage change in body mass from baseline measurements.

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.

Perceived exertion was assessed using the Borg CR-10 scale (Borg, 1998) at 2h, 4h, and 6h time points. Perceived pain was evaluated using a 10-point visual analog scale (0 = no pain, 10 = maximum pain) at all measurement time points. Thermal sensation was assessed using a 9-point scale (-4 = very cold, 0 = neutral, +4 = very hot) (Young, Sawka, EpStein, Decristofano, & Pandolf, 1987), while thermal comfort was evaluated using a 4-point scale (1 = comfortable, 4 = very uncomfortable) (Vargas, Chapman, Johnson, Gathercole, & Schlader, 2018). Thirst sensation was measured using a 9-point scale (1 = not thirsty at all, 9 = very, very thirsty) (Capitán-Jiménez & Aragón-Vargas, 2016). Perceived recovery was assessed at 24h and 48h time points using a 10-point scale (0 = very poorly recovered, 10 = very well recovered) (Laurent et al., 2011). Skin humidity perception was evaluated using a 7-point scale (1 = very dry, 7 = very wet) (Carlucci, Bai, de Dear, & Yang, 2018).

2.4.3 Cardiovascular responses

Systolic and diastolic blood pressure were measured using an automated digital sphygmomanometer (Omron® HEM-7113, Kyoto, Japan) following standardized protocols. Participants remained seated for 5 minutes prior to measurement, with the cuff positioned at heart level. Heart rate was recorded simultaneously with blood pressure measurements. All cardiovascular assessments were performed duplicate, with the average value used for analysis.

2.4.4 Urine measurements

Urine samples were collected at all measurement time points and analyzed immediately using commercial reactive urinalysis strips (URI-TOP® 11 test strips (Biosynex S.A., Illkirch-Graffenstaden, France). The following parameters were assessed: blood (hemoglobin), ketones, glucose, proteins, nitrites, pH, and specific gravity (density). All measurements were performed according to manufacturer instructions, with results read at specified time intervals using the provided color chart. Quality control procedures included verification of strip integrity and adherence to storage conditions.

2.4.5 Environmental Conditions

Ambient variables were continuously monitored throughout the experiment using a calibrated weather station (Auriol®, model H13726A, Spain), with a resolution of 0.1 °C for temperature and 1% for relative humidity. Measurements were obtained at all data collection points to control environmental influences on physiological responses, while wind speed and cloud cover were also registered to provide a complete description of conditions.

During the trial, indoor temperature remained stable at 19.6 ± 0.3 °C at baseline and after two hours, increasing to 22.0 ± 0.8 °C after four hours and 22.7 ± 0.6 °C at the end of the event. Relative humidity showed a gradual decline, from 54.7 ± 0.6% at the start to 54.3 ± 0.6% at two hours, 50.3 ± 2.3% at four hours, and 46.3 ± 2.9% at six hours. Outdoor temperature rose progressively, from 17.0 ± 1.7 °C at baseline to 18.5 ± 0.7 °C at two hours, peaking at 23.3 ± 1.2 °C after four hours and remaining at 23.3 ± 0.6 °C until the end.

2.4.6 Performance Assessment

Distance performance was continuously monitored using digital video recording equipment (Sony® HandyCam, DCR-SR37, Tokyo, Japan) to accurately track lap completion times and calculate cumulative distance covered by each participant during the 6-hour ultramarathon. The event commenced at 8:15 am on a certified 400-meter Olympic standard athletic track. To optimize data collection efficiency during intermediate assessments, participants initiated the race at staggered 2-minute intervals according to a randomized sequence based on bib numbers assigned during the pre-event briefing. Real-time event coordination was facilitated through a pre-recorded audio system that provided individualized instructions to athletes based on their assigned bib numbers. The audio prompts included: (a) individual race start signals; (b) 15-minute pre-assessment nutritional restrictions; (c) reporting instructions for intermediate physiological evaluations; (d) clearance to resume running following the 15-minute assessment period; and (e) event conclusion notifications.

Participants were permitted to employ self-selected pacing strategies throughout the event and wore standard personal running equipment (shorts and short-sleeved shirts). Individual support stations were established along the track grandstand, each identified by the corresponding participant's bib number and stocked with unlimited access to standardized nutrition options (chocolate/cereal bars and bananas) and water. All food and fluid consumption were meticulously recorded to quantify intake patterns. Restroom breaks were accommodated at any time during the event, though participants typically coordinated these with the scheduled 15-minute assessment intervals to minimize performance disruption.

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 ± 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 (ηp^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; ηp^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≤0.001)], 4h [-1.8 kg (-2.5; -1.1; p≤0.001)] and 6 h [-1.8 kg (-2.5; -1.0; p≤0.001)]; 2h vs. 4h [-0.7 kg (-1.1; -0.2; p=.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≤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≤0.001)]. Marathon group showed differences between means observed at Pre vs. 2h [-1.1 kg (-1.6; -0.6; p≤0.001)], 4h [-1.4 kg (-2.0; -0.8; p≤0.001)], 6h [-1.3 kg (-1.9; -0.7; p≤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≤0.001; ηp^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≤0.001)], 4h [1.5 a.u. (1.0; 2.0; p≤0.001)], 6h [1.1 a.u. (0.7; 1.6; p≤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≤0.001)], 4h [-1.0 a.u. (-1.6; -0.5; p≤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≤0.001)], 4h [-1.2 a.u. (-1.8; -0.6; p≤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≤0.001; ηp^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≤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≤0.001), 4h [-1.7 a.u. (-2.5; -0.8; p≤0.001)] and 6h [-1.2 a.u. (-1.9; -0.5; p≤0.001)]. 48h showed too differences vs 2h [-1.5 a.u. (-2.2; -0.8; p≤0.001), 4h [-1.5 a.u. (-2.4; -0.7; p≤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≤0.001; ηp^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≤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≤0.001)], 4h [1.1 a.u. (0.6; 1.6; p≤0.001) and 6h [1.1 a.u. (0.5; 1.7; p≤0.001). At the last, 48h showed differences vs 2h [0.9 a.u. (0.4; 1.4; p≤0.001), 4h [1.1 a.u. (0.6; 1.6; p≤0.001) and 6h [1.1 a.u. (0.4; 1.7; p≤0.001)].

Finally, for the thirst sensation; we observed an isolated effect of the moment of measurement ($F_{2,38}$=13.831; p≤0.001; ηp^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≤0.001)], 4h [2.0 a.u. (1.0; 3.0; p≤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.

	Pre	2 hours	4 hours	6 hours	24h after	48h after
Body Mass (kg)						
Ultra	74.8±10.2[a]	73.7±10.4[b]	73.0±10.2[c]	73.1±10.1[c]	74.1±10.3[d]	74.8±10.1
Marathon	77.2±5.7[e]	76.1±5.8[d]	75.8±5.7[d]	75.9±5.4[d]	76.5±5.6[d]	77.1±5.8
Sub-marathon	78.6±10.3[f]	78.1±10.4	77.8±10.3[d]	77.7±10.4[d]	78.5±10.8	78.6±10.4
Thermal Sensation						
Ultra	3.6±0.7[g]	5.0±1.2	5.5±0.9	5.2±1.1	4.3±0.8[a]	4.1±0.8[a]
Marathon	3.4±0.6[g]	4.9±0.8	5.1±1.1	4.5±0.7	3.9±0.6[a]	3.9±0.5[a]
Sub-marathon	3.7±0.7[g]	5.0±0.6	4.8±0.8	4.3±0.9	4.0±0.4[a]	3.8±0.5[a]
Skin Wettedness						
Ultra	-1.2±1.0[a]	0.5±1.3	0.5±1.3	0.0±1.5	-1.5±0.9[a]	-1.5±0.9[a]
Marathon	-0.9±1.0[a]	0.4±1.0	0.5±1.8	-0.6±1.0	-1.6±0.6[a]	-1.2±0.8[a]
Sub-marathon	-1.2±0.9[a]	-0.3±1.1	-0.3±1.4	-0.3±1.1	-1.3±0.8[a]	-1.2±0.7[a]
Thermal Comfort						
Ultra	3.5±0.9[a]	2.9±0.7	2.2±1.1	2.7±0.6	3.7±0.5[a]	4.0±0.6[a]
Marathon	3.9±0.7[a]	2.8±1.0	3.0±1.2	2.8±1.3	3.9±0.4[a]	3.8±0.7[a]
Sub-marathon	3.8±0.7[a]	3.2±0.8	3.1±0.7	2.8±0.9	3.9±0.3[a]	3.8±0.5[a]
Thirst						
Ultra	2.3±1.6[a]	3.7±1.8	5.3±1.4[c]	4.1±2.7	2.5±1.7	2.2±0.8[h]
Marathon	2.0±1.1[a]	3.5±1.2	4.0±1.9[c]	4.3±2.2	2.6±1.7	1.8±0.9[h]
Sub-marathon	2.6±2.4[a]	3.8±2.0	3.6±1.8[c]	3.9±1.9	3.2±1.6	2.4±1.6[h]

[a] p≤0.038 vs. 2h, 4h and 6h. [b] p≤0.06 vs. 4h, 6h and 48h. [c] p≤0.034 vs. 24h and 48h. [d] p≤0.05 vs. 48h. [e] p≤0.034 vs. The others except 48h. [f] p≤0.007 vs. 4h and 6h. [g] p≤0.034 vs. 2h, 4h, 6h and 24h. [h] p=0.001 vs. 2h and 6h.

For RPE ($F_{2,38}$=32.476; p≤0.001; ηp^2=0.65) and PRS ($F_{2,38}$=12.17; p≤0.001; ηp^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≤0.001)] and 6h [-2.3 a.u. (-3.1; -1.5; p≤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≤0.001)].

For pain there was a significative and isolated effect for moment of measurement ($F_{2,38}$=55.446; p≤0.001; ηp^2=0.897). Where the PRE showed significant difference for all moments of measurement (p≤0.001). 2h showed significative difference for all consecutive moments (p≤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≤0.001)]. 6h showed too difference for 24h [1.8 a.u. (0.8; 2.9; p≤0.001)] and 48 h [3.5 a.u. (2.4; 4.6; p≤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[a]	3.6±1.4[b]	6.0±2.0[c]	6.8±1.9[c]	5.0±1.7	3.2±1.5
Marathon	1.1±1.6[a]	3.6±1.5[b]	5.3±1.9[c]	6.0±1.7[c]	4.4±1.5	2.6±1.5
Sub-marathon	1.0±1.0[a]	2.9±1.1[b]	5.0±1.5[c]	5.7±1.8[c]	3.6±1.4	2.3±1.4

[a] p≤0.001 vs the others. [b] p≤0.044 vs the others except 48h.[c] p≤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≤0.001; ηp^2=0.889). HR at PRE showed differences for 2h [-45.0 bpm (-54.7; -35.3; p≤0.001)]; 4h [-40.2 bpm (-51.0; -29.4; p≤0.001)]; 6h [-37.1 bpm (-47.9; -26.3; p≤0.001)]. 24h showed a significative difference for 2h [-39.7 bpm (-51.1; -28.3; p≤0.001)]; 4h [-34.9 bpm (-45.2; -24.5; p≤0.001)]; 6h [-31.8 bpm (-40.4; -23.1; p≤0.001)] and 48h [9.5 bpm (3.5; 15.4; p≤0.001)]. Systolic blood pressure (SBP) showed too an isolated effect for moment of measurement ($F_{2,38}$=7.055; p≤0.001; ηp^2=0.524). The SBP at PRE presented significative difference to 2h [15.9 mmHg. (3.0; 28.8; p=0.007)]; 4h [17.0 mmHg (6.4; 27.6; p≤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; ηp^2=0.39). The means observed at PRE showed a significative 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[a]	121.7±15.5	115.6±15.6	117.5±11.1	81.5±14.8[b]	68.4±9.9
Marathon	72.6±13.0[a]	117.3±17.4	112.4±16.6	107.9±16.5	72.5±13.6[b]	63.9±12.7
Sub-marathon	67.7±10.3[a]	107.9±16.8	104.3±21.3	97.7±20.7	73.8±11.2[b]	67.2±13.0
			Systolic Blood Pressure (mmHg)			
Ultra	136.4±5.5[c]	113.0±36.4	111.5±12.1	123.4±12.7	128.5±11.4	128.2±6.2[d]
Marathon	131.7±20.2[c]	120.1±14.3	114.6±16.6	114.9±14.1	119.7±12.7	129.5±11.5[d]
Sub-marathon	135.9±18.5[c]	123.1±20.9	126.9±11.5	121.3±17.7	123.3±13.2	128.4±11.3[d]
			Diastolic Blood Pressure (mmHg)			
Ultra	86.5±4.6[c]	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[c]	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[c]	84.7±11.3	86.1±8.4	82.8±9.3	82.7±9.5	84.1±8.6

[a] p≤0.001 this moment of measurement vs. 2, 4 and 6h. [b] p≤0.001 vs the others except Pre. [c] p≤0.022 vs the others except 48h. [d] p≤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; ηp^2 = 0.1); however, the statistical test lacked sufficient power to identify significant differences. Regarding glucose, after applying the Greenhouse-Geisser correction, a Group × Time interaction effect was observed ($F_{1,36}$ = 2.838; p = 0.022; ηp^2 = 0.136). The Sub-marathon group showed a significant difference between the 24-hour measurement and the other time points (p ≤ 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 ≤ 0.001; ηp^2 = 0.695), with significant differences at 6 h and 24 h compared to the other time points (p ≤ 0.032).

A main effect of time of measurement was observed for urine pH ($F_{5,32}$ = 11.617; p ≤ 0.001; ηp² = 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 ≤ 0.003). Finally, a main effect of time of measurement was observed for urine specific gravity (USG) ($F_{5,32}$ = 11.617; p ≤ 0.001; ηp² = 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 ≤ 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 (*RBC/µL;* 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[a]	0±0
Proteins (mg/dL)						
Ultra	0±0	0±0	2.7±9.0	22.7±29.7[b]	24.5±12.1[b]	2.7±9.0
Marathon	0±0	0±0	0±0	21.3±24.3[b]	18.0±15.2[b]	2.0±7.7
Sub-Marathon	5.0±11.7	2.5±8.7	0±0	12.5±15.4[b]	20.0±14.8[b]	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[c]	3.0±3.5[d]	5.1±2.5[d]	6.4±0.5	6.3±0.5	6.3±0.5
Marathon	5.7±1.5[c]	2.3±3.0[d]	2.6±3.1[d]	6.0±0.4	5.7±1.5	6.1±0.3
Sub-Marathon	5.4±1.9[c]	4.2±2.6[d]	4.8±2.4[d]	5.7±0.5	6.1±0.5	6.2±0.7
Urine Specific Gravity ($g.mL^{-1}$)						
Ultra	1.019±0.001[c]	1.024±0.002	1.024±0.009	1.027±0.004[e]	1.022±0.007	1.017±0.001
Marathon	1.022±0.001[c]	1.025±0.004	1.027±0.004	1.027±0.005[e]	1.027±0.004	1.024±0.008
Sub-Marathon	1.022±0.001[c]	1.027±0.005	1.029±0.014	1.029±0.001[e]	1.022±0.007	1.020±0.01

[a] P ≤ 0.05 vs. other time points except PRE; [b] P ≤ 0.05 vs. other time points; [c] P ≤ 0.033 vs. 2h; [d] P ≤ 0.003 vs. 6h, 24h, and 48h; [e] P ≤ 0.037 vs. PRE, 24h, and 48h.

Figure 2 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; ηp^2=0.105). Ultra showed differences between Δ48h-Pre and other moments (p≤0.001). Δ24h-Pre showed difference vs. other moments of measurement (p=0.253). Δ2h-Pre showed difference vs. Δ4h-Pre [-0.7% (-1.2; -0.2; p=0.003)] and Δ6h-Pre [-0.6% (-1.2; -0.1; p=0.024)]. For Marathon, we observed differences between Δ48h-Pre and other moments (p≤0.012). Sub-marathon present differences between Δ48h-Pre and Δ4h-Pre [-1.0% (-2.0; -0.0; p=0.043)] and Δ6h-Pre [-1.1% (-2.1; -0.2; p=0.008)]. About group comparison, at Δ2h-Pre [1.0% (0.1; 1.9; p=0.015)], Δ4h-Pre [1.4% (0.3; 2.4; p=0.008)], Δ6h-Pre [1.2% (0.2; 2.2; p=0.018)] Ultra showed differences vs. Sub-marathon.

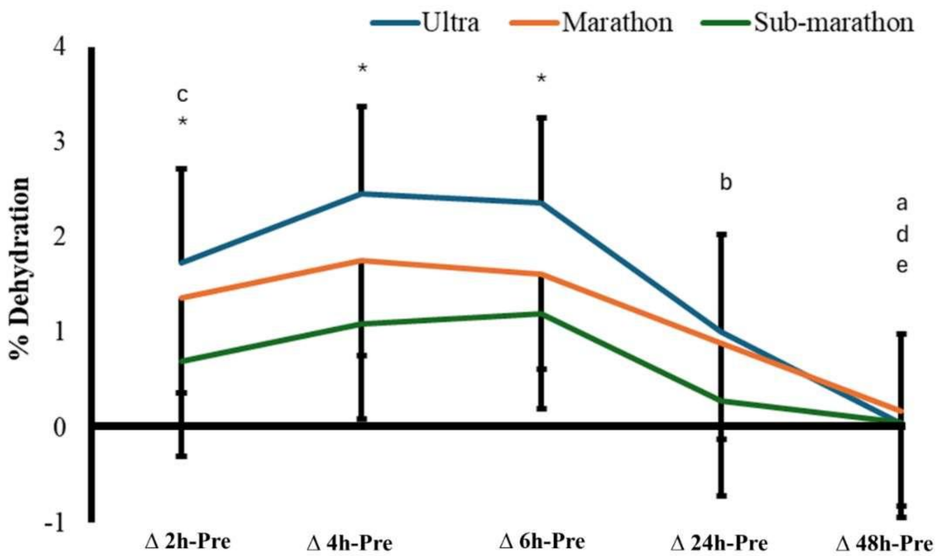

Figure 2. Percentage of dehydration during and after running for Ultra, Marathon and Sub-marathon groups. [a] p≤0.001 vs. others for Ultra. [b] p≤0.002 vs. others except ∆2h-Pre for Ultra. [c] p≤0.024 vs. ∆4h-Pre and ∆6h-Pre for Ultra. [d] p≤0.012 vs. others for Marathon. [e] p≤0.043 vs. ∆4h-Pre and ∆6h-Pre for Sub-marathon. * p≤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. Conducted under thermoneutral environmental conditions, this research provides a controlled framework for interpreting the physiological and perceptual adjustments observed during and after prolonged endurance running.

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, even under thermoneutral conditions, offers a low-cost and efficient way to optimize performance, guide pacing, prevent hyperthermia or heat collapse, 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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APLICAÇÕES PRÁTICAS

Os resultados desta tese trazem contribuições relevantes para o treinamento, a recuperação e a segurança de corredores de longa duração. Conduzida em ambiente termoneutro, esta pesquisa permitiu compreender, de forma controlada e detalhada, como as respostas fisiológicas e perceptuais se comportam durante e após um esforço contínuo de seis horas, revelando padrões importantes de fadiga e recuperação.

A principal implicação prática está na relação entre velocidade, temperatura da pele e percepção de esforço ao longo da corrida. O aumento progressivo da temperatura corporal e da percepção subjetiva de esforço acompanhou a queda natural do ritmo, reforçando a utilidade do monitoramento térmico e perceptivo em tempo real. Essas medidas simples podem auxiliar treinadores e atletas na manutenção do ritmo-alvo, na prevenção de fadiga precoce e na detecção antecipada de sinais de sobrecarga térmica.

Outro achado relevante foi a constatação de que a recuperação completa após esforços prolongados pode demandar mais de 24 horas, especialmente entre atletas que percorrem maiores distâncias. Alterações persistentes em variáveis fisiológicas (como frequência cardíaca, massa corporal e pressão arterial) e perceptuais (como dor, desconforto térmico e percepção de esforço) indicam que estratégias de recuperação devem ser individualizadas de acordo com o volume percorrido e o perfil do atleta.

O monitoramento simultâneo de marcadores fisiológicos e perceptuais mostrou-se uma ferramenta acessível, sensível e aplicável em contextos reais de campo. Escalas de percepção como esforço, dor, sede e conforto térmico, associadas ao controle da massa corporal permitem acompanhar o estado de fadiga e ajustar o treinamento sem necessidade de equipamentos sofisticados. Esse tipo de acompanhamento é especialmente útil em provas longas ou situações em que o acesso a instrumentos laboratoriais é limitado.

Além disso, a compreensão das dinâmicas térmicas e cardiovasculares observadas neste estudo reforça a importância de estratégias preventivas e de resfriamento ativo — como molhar a pele, aplicar gelo ou buscar sombreamento — para melhorar o conforto térmico, evitar hipertermia e reduzir o risco de colapso pelo calor em ambientes quentes e úmidos.

Por fim, os resultados reforçam a necessidade de ampliação das pesquisas com populações diversas (como mulheres e corredores recreacionais) e com inclusão de novos marcadores metabólicos (como sódio no suor, osmolalidade e creatina quinase). Tais avanços poderão aprimorar ainda mais o entendimento sobre os mecanismos de fadiga e recuperação e subsidiar protocolos personalizados de treinamento e recuperação para provas de resistência e ultraendurance.

Em síntese, a integração entre marcadores fisiológicos e perceptuais representa uma abordagem prática, de baixo custo e alta aplicabilidade para otimizar a performance, prevenir riscos térmicos e proteger a saúde de corredores submetidos a esforços prolongados.

CONSIDERAÇÕES FINAIS

Esta tese teve como objetivo analisar e comparar as respostas cardiovasculares, metabólicas e perceptuais em corredores masculinos treinados antes, durante e após uma corrida contínua de seis horas, com ênfase na termorregulação e no comportamento da temperatura da pele ao longo do esforço e da recuperação. O estudo envolveu 39 soldados de elite submetidos a um protocolo de corrida de longa duração sob condições termoneutras, o que possibilitou observar de forma detalhada os ajustes fisiológicos e perceptuais durante o esforço e nas 48 horas subsequentes.

Os resultados demonstraram que as respostas fisiológicas e perceptuais variam de acordo com o volume total percorrido, destacando que os atletas que correram maiores distâncias apresentaram maior estresse térmico e cardiovascular, bem como recuperação mais lenta de parâmetros hemodinâmicos e perceptuais. Além disso, observou-se que variáveis como temperatura da pele (em especial da coxa) e percepção subjetiva de esforço correlacionam-se inversamente com a distância percorrida, reforçando a relevância dessas medidas como indicadores práticos de fadiga e regulação do desempenho.

Esses achados apontam para a importância do monitoramento integrado de marcadores fisiológicos, metabólicos e perceptuais, uma vez que permitem compreender de maneira mais completa as demandas impostas por esforços prolongados e o impacto do estresse térmico sobre a performance. Escalas subjetivas de esforço, desconforto térmico e dor, associadas a medidas simples como a variação da massa corporal e o registro da temperatura da pele, mostraram-se ferramentas acessíveis e sensíveis para o acompanhamento da carga interna e do estado de recuperação, mesmo em contextos de campo.

Do ponto de vista prático, as evidências desta tese indicam que estratégias de recuperação devem ser individualizadas conforme o perfil e o volume de corrida, podendo demandar períodos superiores a 24 horas para a restauração completa de parâmetros fisiológicos e perceptivos. Além disso, o acompanhamento contínuo da temperatura corporal e da percepção de esforço pode orientar decisões em tempo real sobre ritmo e hidratação, prevenindo situações de hipertermia e colapso pelo calor, especialmente em ambientes quentes e úmidos. Intervenções como resfriamento cutâneo, sombreamento e hidratação planejada surgem como estratégias complementares eficazes para manutenção da segurança e do desempenho.

Como limitações, destacam-se a amostra composta exclusivamente por homens militares altamente treinados e a ausência de controle rigoroso sobre variáveis individuais como alimentação, sono e hidratação, o que restringe parcialmente a generalização dos resultados para outros perfis populacionais.

Para futuras pesquisas, recomenda-se ampliar a investigação para diferentes grupos (incluindo mulheres e corredores recreacionais), incorporar biomarcadores adicionais — como sódio no suor, osmolalidade e creatina quinase — e avaliar intervenções de recuperação, como estratégias de resfriamento e imersão em água fria. O uso de tecnologias de monitoramento contínuo da temperatura da pele e da frequência cardíaca também representa um avanço promissor para aplicações no treinamento e na prevenção de riscos térmicos.

Conclui-se que a integração entre marcadores fisiológicos e perceptuais representa uma abordagem eficiente, acessível e aplicável para compreender os desafios da termorregulação em corridas de longa duração. Essa perspectiva contribui para otimizar a performance, aprimorar estratégias de recuperação e, sobretudo, preservar a saúde e a segurança de atletas expostos a condições extremas de esforço e temperatura.

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Apêndice A – Termo de Consentimento Livre e Esclarecido

POLITÉCNICA

INEF

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.

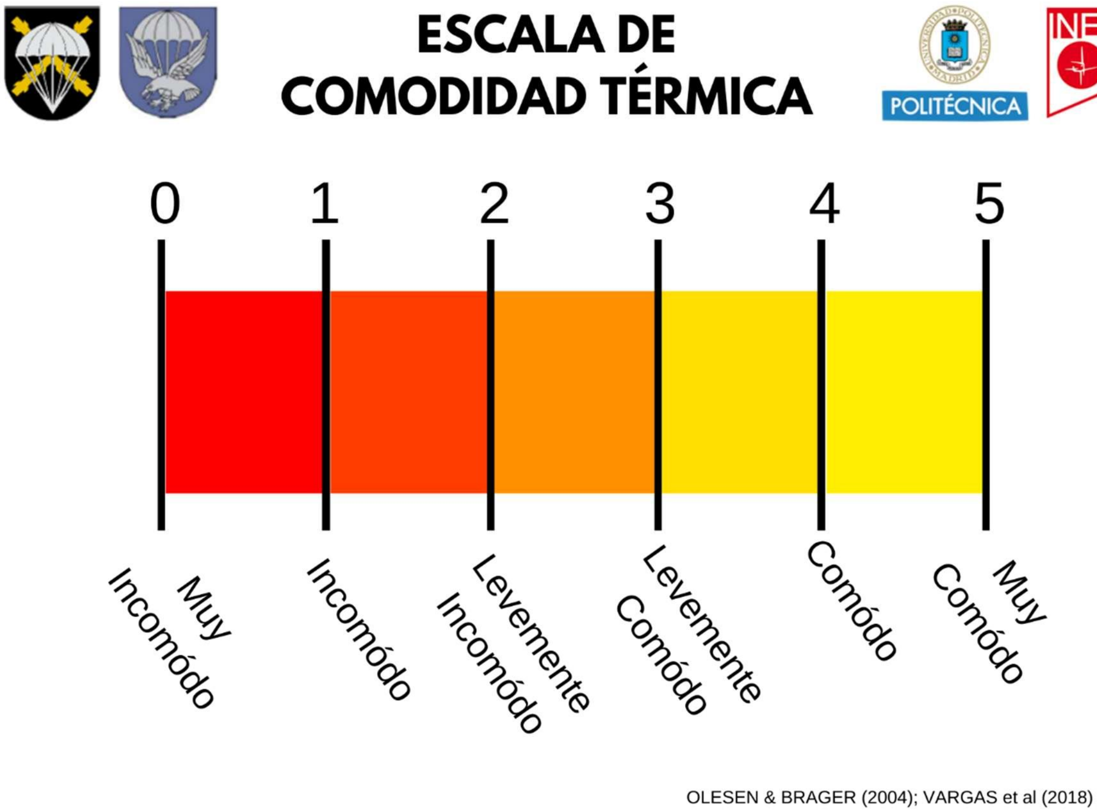
Agradeciendo de antemano su colaboración. Para cualquier consulta no dude ponerse en contacto con el responsable del proyecto (Profesor Dr. Manuel Sillero Quintana:

Yo D/Dª ________________________________, 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.

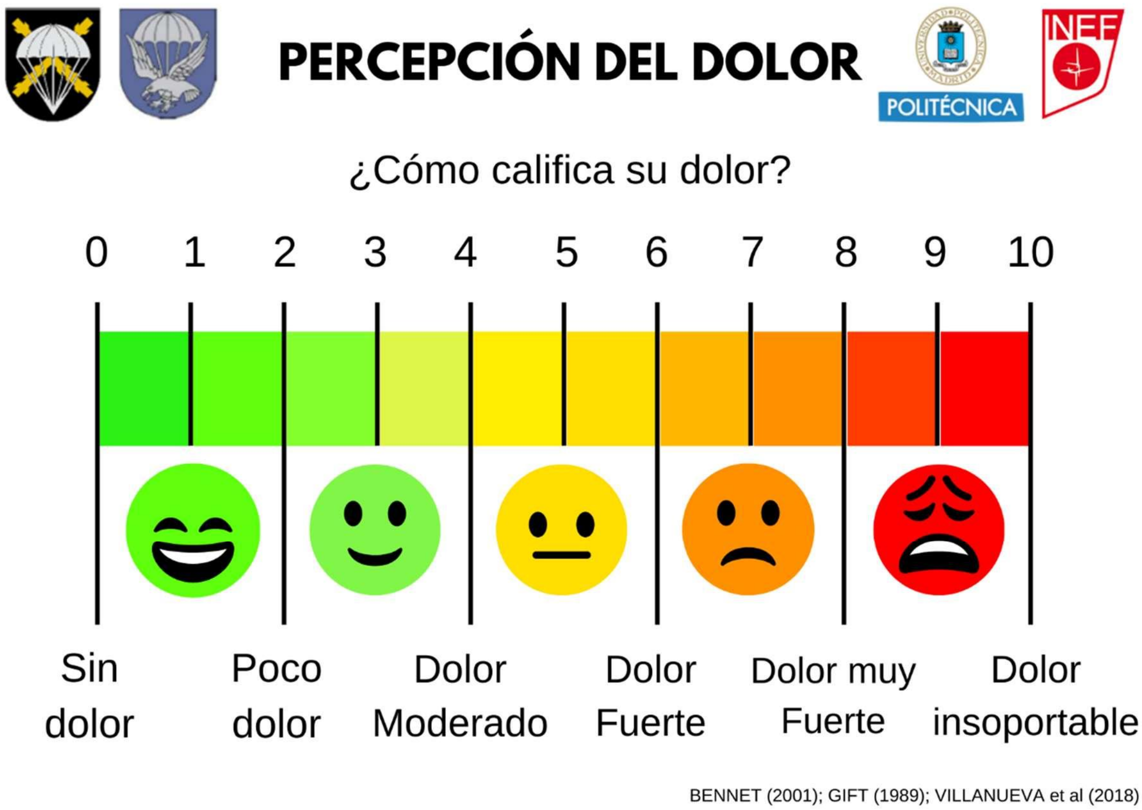
He leído, comprendo la información presentada y permito que se traten los datos con la única finalidad científica y de difusión entre los mandos de la Ejercito Español, en tanto se respeten la confidencialidad y el anonimato de estos, y el tratamiento se efectúe previo procedimiento de disociación, de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

Firmado: Autorizado:

Apêndice B – Escala de Conforto Térmico

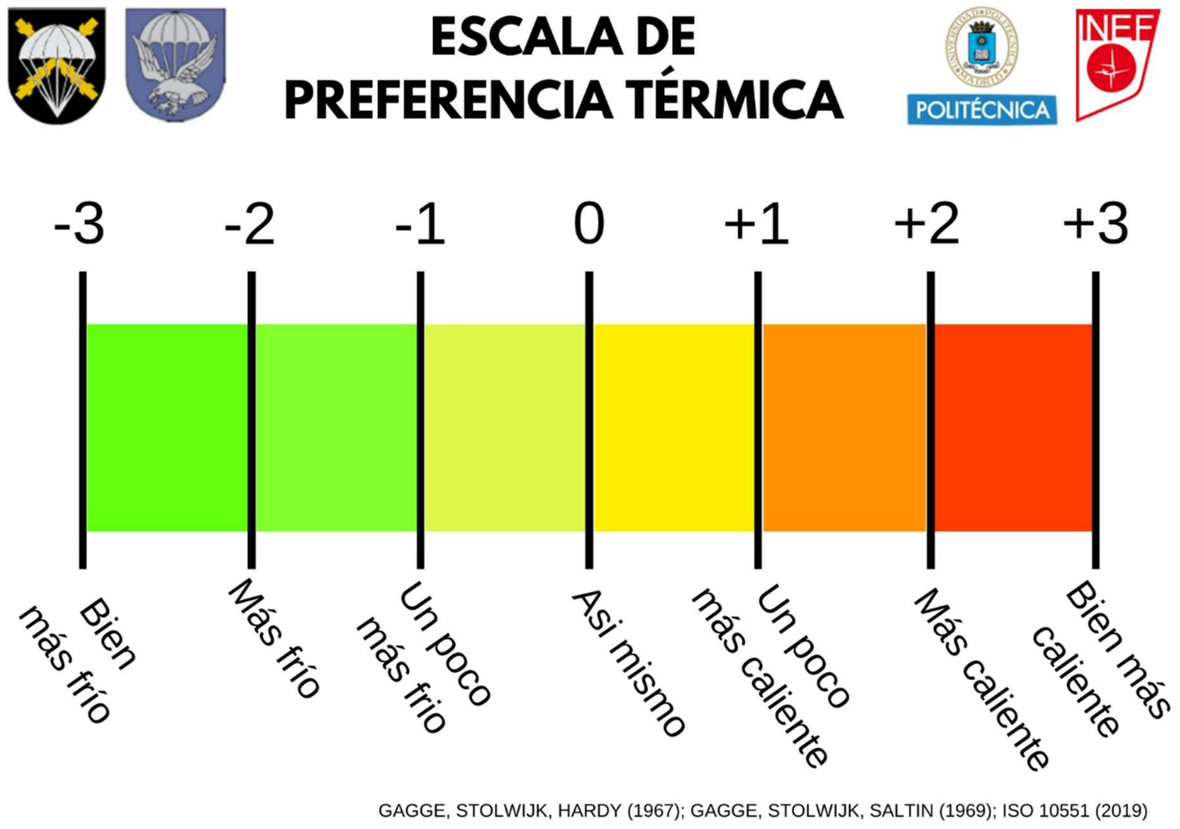


Apêndice C – Escala de Percepção de Dor

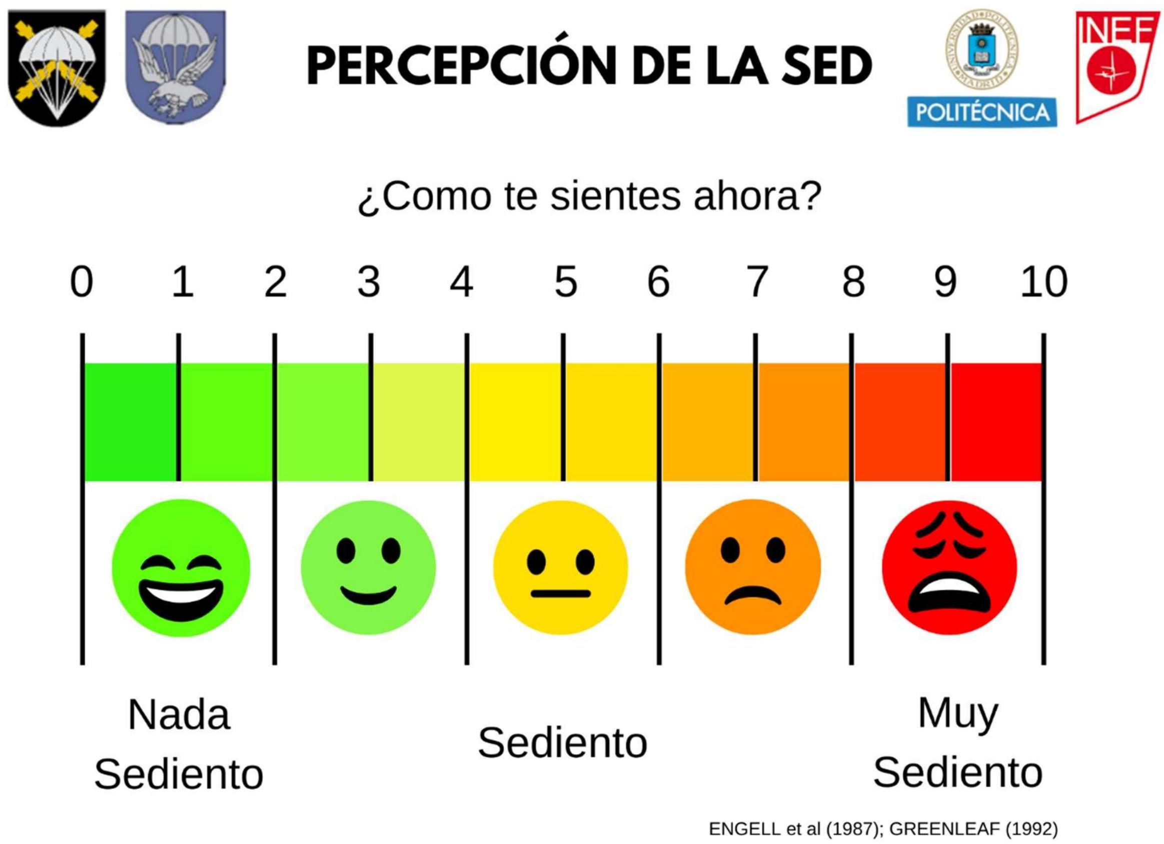


Apêndice D – Escala de Percepção de Umidade da Pele

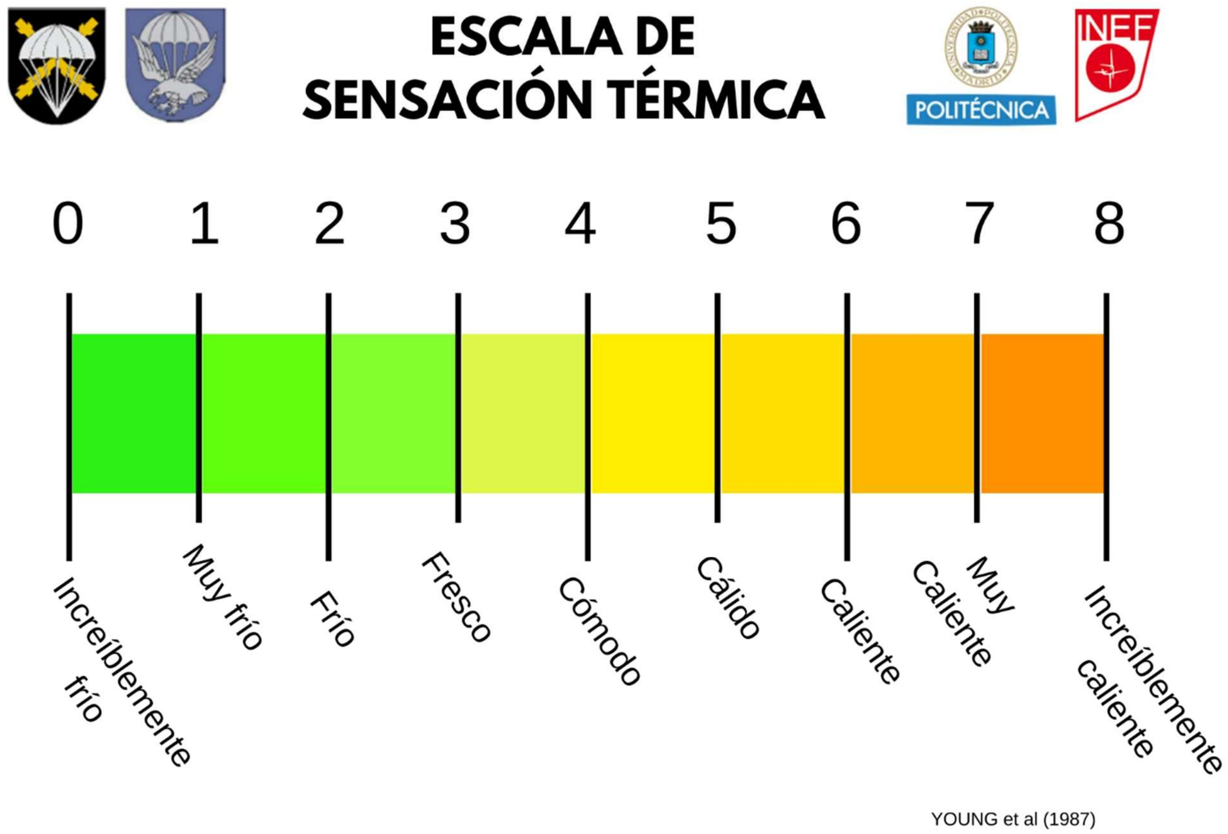
Apêndice E – Escala de Preferência Térmica



Apêndice F – Escala de Percepção de Sede



Apêndice G – Escala de Sensação Térmica



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*

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

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

Apêndice I – Escala Subjetiva de Recuperação (SRS)

ESCALA DE *RECUPERACIÓN*

0	***Muy mal recuperado***
1	
2	***Muy poco recuperado***
3	
4	***Algo recuperado***
5	***Adecuadamente recuperado***
6	***Moderadamente recuperado***
7	
8	***Bien recuperado***
9	
10	***Muy bien recuperado***

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

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 influyera 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? ☐ NO ☐ SÍ	
¿Cual? _______________________________ **¿Utilizas algún medicamento?** ☐ NO ☐ SÍ	
SI COMPITES EN LA ACTUALIDAD CARRERAS ¿En que distancias?:	
☐ No compito en carrera ☐ 5 a 10 km ☐ 11 a 21 km ☐ 22 a 42 km ☐ Más que 42	
¿Has competido en alguna prueba de más de 3 horas?: ☐ SI ☐ NO ¿Cuántas aprox.? ____________	
Entrenamiento en los últimos 3 meses: Entrenamientos por semana (promedio):_________ Duración de la sesión (promedio): ________ minutos	**Volumen semanal (Si se conoce)** TOTAL (promedio): _____ km
OBSERVACIONES:	

ENTRENAMIENTOS DE INSTRUCCIÓN en los últimos 3 meses:		
DISTANCIA (APROX)	**DURACIÓN**	**¿CUANTOS?**
___________ **Km**	___________ **horas**	
___________ **Km**	___________ **horas**	
___________ **Km**	___________ **horas**	
___________ **Km**	___________ **horas**	
OTROS ENTRENAMIENTOS		
Musculación ☐ NO ☐ SÍ	**Crossfit o similar** ☐ NO ☐ SÍ	**Pilates o similar** ☐ NO ☐ SÍ

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: ☐ Carrera continua ☐ Correr y andar ☐ Andar ☐ No lo sé
Estrategia de prueba (3 tramos): ☐ Todos igual ☐ De menos a más ☐ De más a menos ☐ No lo sé

(continuação)

HOJA DE REGISTRO DE DATOS
SALTOS

"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
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								TRAS 24h				TRAS 48h			
					Pre-				2 horas				4 horas				Post				Post-30											
	ST	SED	HU	CO	ST	SED	HU	CO	ST	SED	HU	CO	ST	SED	HUM	CO	ST	SED	HUM	CO	ST	SED	HUM	CO	ST	SED	HUM	CO	ST	SED	HUM	CO
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HOJA DE REGISTRO DE DATOS
TEMPERATURA TIMPÁNICA

"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
TERMOGRAMAS

"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
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	
			Pre-		2 horas		4 horas		Post		Post-30					
	PESO	TALLA	PESO	TALLA	PESO 01	PESO 02	PESO 01	PESO 02	PESO 01	PESO 02	PESO 01	TALLA	PESO	TALLA	PESO	TALLA
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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			
	AGUA	BARRITAS	BANANA	CHOCOLATE	AGUA	BARRITAS	BANANA	CHOCOLATE	AGUA	BARRITAS	BANANA	CHOCOLATE
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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		
				Pre-			2 horas			4 horas			Post			Post-30								
	P.A.S	P.A.D	FC	P.A.S	P.A.D	FC	P.A.S	P.A.D	FC	P.A.S	P.A.D	FC	P.A.S	P.A.D	FC	P.A.S	P.A.D	FC	P.A.S	P.A.D	FC	P.A.S	P.A.D	FC
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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		
				Pre-			2 horas			4 horas			Post			Post-30								
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Anexo A – Aprovação pelo Comitê de Ética em Pesquisa da Universidade Federal de Juiz de Fora

COMITÊ DE ÉTICA DA PESQUISA COM SERES HUMANOS | ufjf

UFJF - UNIVERSIDADE FEDERAL DE JUIZ DE FORA - MG

Plataforma Brasil

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 ss 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 Nº001/2013 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 do Parecer: 3.085.114

Aprovado

Necessita Apreciação da CONEP:
Não

JUIZ DE FORA, 14 de Dezembro de 2018

Assinado por:
Jubel Barreto
(Coordenador(a))

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