



U N I V E R S I D A D E
LUSÓFONA

**Centro Universitário de Lisboa
Faculdade de Educação Física e Desporto
Doutoramento em Educação Física e Desporto**

**O EFEITO DA TEMPERATURA AMBIENTE NA
PERFORMANCE FÍSICA E ANTECIPATÓRIA EM
FUTEBOLISTAS SENIORES FEMININAS**

Tese de Doutoramento defendida em provas públicas para a obtenção do Grau de Doutor
em Educação Física e Desporto, na especialidade de Didática da Educação Física e Desporto,
orientada pelo Professor Doutor Filipe Luís Martins Casanova

ALBERTO POMPEO DOS SANTOS / N° 21910163

2024



UNIVERSIDADE
LUSÓFONA

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“Versão Final”

Tese defendida em provas públicas na Universidade Lusófona - Centro Universitário de Lisboa no dia 19/06/2024, perante o júri, nomeado pelo Despacho de Nomeação N.º: 812/2024, de 16 de abril de 2024, com a seguinte composição:

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ALBERTO POMPEO DOS SANTOS / N° 21910163

2024

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Pompeo, A. (2024). N° de estudante 21910163. O efeito da temperatura ambiente na performance física e antecipatória em futebolistas seniores femininas. Versão final de tese a prova pública, apresentada para obtenção do grau de Doutor em Educação Física e Desporto. Faculdade de Educação Física e Desporto, Universidade Lusófona – Centro Universitário de Lisboa. Lisboa, Portugal.

AGRADECIMENTOS

Gostaria de expressar minha profunda gratidão a todas as pessoas que desempenharam papéis fundamentais na jornada do meu doutoramento na Universidade Lusófona de Lisboa.

Primeiramente eu agradeço a Deus.

À Universidade Lusófona de Lisboa que me proporcionou a oportunidade de realizar este doutoramento. Ao Diretor da Faculdade de Educação Física e Desporto da Universidade Lusófona, Professor Doutor Jorge Proença, que não apenas liderou a insituição, mas também me possibilitou iniciar minha carreira como docente universitário.

Aos Diretores do 3º Ciclo de Estudos, Professor Doutor Francisco Carreiro da Costa e Professor Doutor António Palmeira, expresso minha gratidão pelo valioso direcionamento ao longo da formação acadêmica.

Quero agradecer, também, o Professor Paulo Cunha por todo o auxílio ao longo da minha trajetória no doutoramento.

À incansável secretária da Faculdade de Educação Física e Desporto, Dra. Susana Cordeiro, agradeço por sua inestimável ajuda e suporte administrativo.

Aos meus orientadores, que desempenharam um papel crucial na minha formação acadêmica, em particular: ao meu orientador, Professor Doutor Filipe Casanova, que vai além de ser apenas um professor em minha vida, tornou-se uma figura paterna e inspiradora e aos meus coorientadores, Professor Doutor Júlio Costa e Professor Doutor Mark Williams, pelo seu valioso contributo e orientação.

A todos os membros do Centro de Alto Rendimento do Jamor, em especial ao Doutor João Beckert, Doutor João Paulo Delgado e Doutor Diogo Simões, agradeço pela colaboração nos meus estudos experimentais.

Quero expressar minha profunda gratidão a todos os membros do Departamento Feminino do Sport Lisboa e Benfica, uma parte essencial da minha jornada acadêmica e profissional. Em particular, gostaria de estender meus agradecimentos calorosos aos meus dedicados companheiros do Departamento de Análise e Observação.

Agradeço aos meus colegas Pedro, Fábio e Mauro, cuja colaboração e trabalho em equipe contribuíram significativamente para o nosso desempenho coletivo.

Em especial, quero expressar minha sincera gratidão ao Professor Nuno Maurício, cuja generosidade e confiança me proporcionaram uma oportunidade única. Sua orientação e liderança foram inestimáveis, moldando não apenas meu desenvolvimento profissional, mas também minha experiência no Sport Lisboa e Benfica.

Expresso minha gratidão aos amigos que se tornaram parte significativa desta jornada, nomeadamente: aos amigos do Porto, Kaueh, Bruno, Vinícius, Dayanna, Alexandre, Giorjines, Alessandra e, especialmente, meu grande amigo Cássio; aos amigos em Lisboa, meus colegas de Doutorado, Vanessa, e meu amigo Everton e sua família, que ofereceram apoio ao longo dessa jornada; ao Leonardo Monteiro por sua amizade; aos amigos de Porto Alegre, colegas da época de escola e meu grande amigo Ricardo Medeiros, e em especial a Luis, César e Cris, que, apesar da distância, jamais me esqueceram.

Por fim, e acima de tudo, agradeço aos meus pais, Luis Alberto e Elaine, pelo amor incondicional e pelo apoio que tornaram possível cada passo desta jornada acadêmica. É graças a vocês que estou escrevendo este agradecimento com um coração cheio de gratidão.

RESUMO

A presente tese de doutoramento foi constituída por três estudos científicos e teve como objetivo geral analisar o efeito da temperatura ambiente no desempenho físico e antecipatório em jogadoras de futebol de elite após a realização de um protocolo de exercício intermitente. E, os objetivos específicos definidos foram: (i) identificar, selecionar e analisar sistematicamente a literatura acerca da relação que o efeito da temperatura ambiente exerce nas demandas físicas e nos julgamentos antecipatórios de jogadores e jogadoras de futebol durante a realização de protocolos de exercício específicos do futebol; (ii) analisar o efeito de um protocolo de exercício intermitente na taxa de produção da força em jogadoras de futebol de elite portuguesas através do teste de salto em contramovimento e (iii) analisar o efeito da temperatura ambiente nas habilidades físicas e antecipatórias em futebolistas do sexo feminino durante a realização de um protocolo de exercício intermitente.

No primeiro estudo realizado as bases de dados utilizadas foram a PubMed, Scielo, Scopus, SPORTDiscus e Web of Science. O segundo estudo (piloto) avaliou o efeito de um protocolo de esforço intermitente na taxa de produção da força explosiva através do teste de salto em contramovimento em 12 jogadoras de futebol de elite portuguesas. O terceiro estudo experimental analisou como a temperatura ambiente elevada (38° C) afeta o desempenho físico e a capacidade de antecipação de 21 jogadoras de futebol de elite feminino durante um protocolo de exercício intermitente indutor de fadiga. As participantes realizaram saltos em contramovimento e responderam a ações de jogo ofensivas filmadas em condições de temperatura ambiental de 20° C e 38° C, com uma semana de intervalo entre as condições.

Os resultados obtidos nos diferentes estudos evidenciaram: (i) 1.289 estudos científicos foram encontrados na literatura da especialidade, no entanto nenhum dos artigos atendeu aos critérios P.I.C.O.S. adotados, resultando em um total de zero artigos elegíveis; (ii) as futebolistas de elite apresentaram um decréscimo significativo do salto em contramovimento ($p < 0.01$) entre os dois momentos de avaliação (pré vs pós-protocolo); (iii) em condições de temperatura ambiente amena, e após a realização do protocolo de exercício intermitente, as futebolistas apresentaram uma redução de desempenho no salto em contramovimento ($p < 0,05$), mas esta redução foi superior quando as futebolistas foram expostas a condições de elevada temperatura ambiente ($p < 0,05$). Também, a exposição a elevada temperatura ambiente provocou decréscimos significativos na capacidade antecipatória das futebolistas quando comparada às condições de temperatura ambiente amena (64,41% vs 53,44%; $p < 0,001$).

Assim, a presente tese de doutoramento demonstrou que se verificou uma carência de estudos científicos para melhor compreender o efeito que a temperatura ambiente exerce nos desempenhos físicos e antecipatórios das jogadoras de futebol; o protocolo de exercício intermitente a que as futebolistas de elite foram sujeitas induziu uma redução no desempenho do salto em contramovimento; e, por último, a exposição ao exercício em elevada temperatura ambiente reduziu significativamente o desempenho físico e cognitivo das futebolistas seniores femininas.

Palavras-chave: Futebol; Feminino; Força; Antecipação; Condições ambientais.

ABSTRACT

This doctoral thesis integrated three scientific studies and its general aim was to analyze the effect of ambient temperature on physical and anticipatory performance in elite female soccer players after performing an intermittent exercise protocol. Moreover, the specific aims were: (i) to systematically identify, select and analyze the literature on the relationship that the effect of ambient temperature has on the physical demands and anticipatory judgments of soccer players during the performance of football-specific exercise protocols; (ii) to analyze the effect of an intermittent exercise protocol on strenght in Portuguese elite soccer players through the countermovement jump test and (iii) to analyze the effect of ambient temperature on physical and anticipatory skills in female footballers during the performance of an intermittent exercise protocol.

In the first study, the databases used were PubMed, Scielo, Scopus, SPORTDiscus and Web of Science. The second study (pilot) evaluated the effect of an intermittent exercise protocol on strenght using the countermovement jump test in 12 elite Portuguese soccer players. The third experimental study analyzed how high ambient temperature (38° C) impact the physical performance and anticipatory ability of 21 elite female soccer players during a fatigue-inducing intermittent exercise protocol. The participants performed countermovement jump and responded to offensive game actions filmed in ambient temperature conditions of 20° C and 38° C, with a one-week interval between conditions.

The results obtained from the different studies showed: (i) 1,289 scientific studies were found in the specialist literature, however none of the articles met the P.I.C.O.S. criteria adopted, resulting in a total of zero eligible articles; (ii) elite female footballers showed a significant decrease in countermovement jump ($p < 0.01$) between the two moments (pre- vs. post-protocol); (iii) in mild ambient temperature conditions, and after performing the intermittent exercise protocol, the female footballers showed a reduction in countermovement jump performance values ($p < 0.05$), but this reduction was greater when the participants were exposed to high ambient temperature conditions ($p < 0.05$). Exposure to high ambient temperature also caused significant decreases in the footballers' anticipatory ability when compared to mild ambient temperature conditions (64.41% vs 53.44%; $p < 0.001$).

Thus, this doctoral thesis has shown that there is a lack of scientific studies to better understand the effect that ambient temperature has on the physical and anticipatory performance of football players; the intermittent exercise protocol to which elite football players were subjected induced a reduction in the countermovement jump performance; and, finally, exposure to exercise in high ambient temperature significantly reduced the physical and cognitive performance of female elite football players.

Keywords: Soccer; Female; Strength; Anticipation; Environmental conditions.

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LISTA DE ABREVIATURAS

	INGLÊS	PORTUGUÊS
Km/h	Kilometers per hour	Quilômetros por hora
Tc	Core Temperature	Temperatura Corporal
FIFA	Internationale de Football Association	Federação Internacional de Futebol
UN	United Nations	Organização das Nações Unidas
Kg	Kilogram	Quilograma
BMI	Body Mass Index	Índice de massa corporal
W	Watts	-
CMJ	Counter Movement Jump	Salto em contramovimento
Cm	Centimeters	Centímetros
COI	-	Comitê Olímpico Internacional
IC ou CI	Confidence Interval	Intervalo de Confiança
β	Beta	-
η^2	Partial Eta Squared	Eta ao quadrado
PhD	Doctoral Degree	Doutorado
HRmax	Maximum Heart Rate	Frequência Cardíaca Máxima
NCAA	National Collegiate Athletic Association	Associação Atlética Universitária Nacional
°C	Celsius Degree	Graus Celsius
REMC	Restricted Maximum Likelihood	Probabilidade Máxima Restrita
N	Newtons	-
LMN	Linear Mixed Model	Modelo Linear Misto
m/s	Meters per second	Metros por segundo

INTRODUÇÃO GERAL

O futebol é muito mais do que um esporte, é uma paixão global que transcende culturas e fronteiras (Crocì & Ammirante, 1999). Em todo o mundo, milhões de pessoas acompanham e praticam o futebol, tornando-o uma parte essencial da sociedade contemporânea (Costa Ciampa et al., 2010). No entanto, quando se trata de pesquisas acadêmicas relacionadas ao futebol, se verifica uma tendência histórica de focar principalmente no futebol masculino, relegando o futebol feminino a um segundo plano (Hoffmann et al., 2006). Assim, a presente tese de doutoramento representa um esforço pioneiro e essencial para preencher essa lacuna, reconhecendo a importância do futebol feminino e explorando a influência da temperatura (temperatura ambiente amena vs temperatura ambiente elevada) no desempenho físico e cognitivo das futebolistas de elite.

O futebol feminino tem crescido exponencialmente nas últimas décadas, ganhando visibilidade e reconhecimento mundial (Kjær & Agergaard, 2013). O desenvolvimento do futebol feminino ao longo dos anos representa uma jornada notável de crescimento e evolução em várias frentes, especialmente no âmbito esportivo e profissional (Culvin, 2021). Uma das mudanças mais marcantes no futebol feminino foi a ascensão do profissionalismo (Culvin, 2019). Aliás, nas últimas décadas, se testemunha um aumento significativo no número de ligas e clubes que oferecem contratos profissionais para as futebolistas (Klein, 2018), o que, juntamente com o aumento da competitividade e do compromisso das jogadoras em alcançar níveis de excelência cada vez mais elevados, se torna imperativo que a pesquisa científica acompanhe esse progresso e contribua para a compreensão dos fatores que afetam o desempenho das futebolistas.

Nos últimos anos, a comunidade científica tem procurado acompanhar, de perto, o tema da exposição dos futebolistas durante a competição a condições de temperaturas elevadas. Essa temática, que ganhou notoriedade nas discussões esportivas e científicas, tornou-se um foco de preocupação desde a edição da Copa do Mundo de 2014 (Chmura et al., 2017), realizada no Brasil, e permaneceu como um tema crucial na Copa do Mundo de 2022, no Catar (Sofotasiou et al., 2015).

Recentemente, o Comitê Olímpico Internacional (COI) destacou a necessidade de médicos e pesquisadores científicos colaborarem na obtenção de dados sobre a população específica de atletas de elite que praticam exercícios em ambientes desafiadores (Bergeron et al., 2012). Várias federações internacionais, incluindo a *Fédération Internationale de*

Football Association (FIFA), responderam a este desafio criando um sistema de vigilância para avaliar as condições ambientais durante suas competições (Racinais et al., 2015).

A exposição ao calor parece ter um impacto significativo na performance em futebolistas (Maughan et al., 2010), afetando não apenas seu desempenho técnico, mas também seus fatores de rendimento físico e cognitivo (Bandelow et al., 2010). Sob elevadas temperaturas, o corpo humano enfrenta um desafio considerável para manter a temperatura interna estável (Tattersall et al., 2012), em que os futebolistas são particularmente vulneráveis a essas condições adversas devido à natureza intensa e dinâmica do jogo (Shirreffs et al., 2005).

O calor excessivo aumenta a sudorese dos futebolistas, levando a uma perda rápida de líquidos e eletrólitos (Bergeron, 2003). Isso pode resultar em desidratação, o que compromete a capacidade do corpo em regular a temperatura interna (Maughan & Shirreffs, 2010). Além disso, a desidratação afeta a resistência física, a força muscular e a coordenação motora (Périard et al., 2012).

A força é uma valência fundamental na dimensão física do futebolista, estando diretamente ligada à habilidade dos jogadores em saltar mais alto, correr mais rápido e manter a posse de bola sob pressão (Silva et al., 2015). Também, a força influencia o desempenho individual dos futebolistas de várias maneiras, ou seja, jogadores mais fortes têm a capacidade de imprimir mais potência em seus remates a baliza, aumentam a sua resistência em sprints e tem maior resistência a desarmes de adversários (Rønnestad et al., 2011). Além disso, a força é crucial na prevenção de lesões, uma vez que futebolistas mais fortes tendem a ser mais resistentes ao aparecimento de lesões musculares (Croisier et al., 2008). Não obstante, a força também contribui para a resistência geral, permitindo que os futebolistas mantenham um alto nível de desempenho ao longo de uma partida (Rønnestad et al., 2011).

Assim, a capacidade dos futebolistas em gerar força foi objeto de estudo por Morcillo et al. (2015). Os autores se propuseram estudar a influência de um protocolo indutor de fadiga na capacidade de produção de força (através do salto de contramovimento- CMJ) em 18 jogadores de futebol que jogam em uma equipe profissional da Primeira Divisão da Liga Nacional Espanhola. Os resultados encontrados permitiram verificar uma perda de 8% na altura do salto entre o momento pré-fadiga e pós-fadiga.

Por outro lado, e em relação ao sistema cognitivo, o calor parece afetar

negativamente a função cerebral dos jogadores (Bandelow et al., 2010). A temperatura ambiente elevada acelera o processo de desidratação, que resulta em uma redução na velocidade do processamento cognitivo, afetando a memória de curto prazo e a habilidade de tomar decisões rápidas e assertivas (Adan, 2012). Inclusivamente, em condições extremas, futebolistas podem experimentar confusão mental e falta de concentração, o que compromete seu desempenho tático e estratégico em campo (Smith et al., 2018).

A antecipação e a tomada de decisão no futebol são habilidades cruciais que transcendem a mera técnica dos futebolistas (Williams & Reilly, 2000). Estar à frente do jogo, ler as jogadas antes de acontecerem e tomar decisões eficazes e eficientes são elementos fundamentais para o sucesso no campo (Carling et al., 2008). A capacidade de antecipar os movimentos dos adversários, ler o jogo e agir proativamente é tão valiosa quanto a destreza técnica, já que isso permite que os futebolistas se posicionem adequadamente e ajam com eficiência, muitas vezes antes mesmo da jogada se desenrolar completamente (Rojas Ferrer et al., 2020).

Embora não tenha sido realizado com futebolistas do sexo feminino, Donnan et al. (2022) investigaram o efeito da exposição à temperatura ambiente elevada (32° graus Celsius- C, 50% Umidade relativa- UR) e à temperatura ambiental amena (18°C, 50% UR) no desempenho físico e na tomada de decisão em nove futebolistas do sexo masculino, após completarem em cicloergômetro um protocolo de sprint intermitente com duração de 92 minutos e, simultaneamente, responderem a um conjunto de cenários extraídos do jogo de futebol. Dos resultados observados, se destacaram que o grau de acerto da tomada de decisão foi significativamente prejudicado na condição de calor em comparação com a condição de temperatura ambiente amena.

Atualmente, a disparidade de praticantes da mesma modalidade esportiva em sexos diferentes no mundo do esporte é um tópico amplamente discutido e documentado pela comunidade científica e desportiva (Carvalho, 2023). Quando se trata de estudos e pesquisas relacionados ao futebol, uma diferença notável se destaca, isto é, a maioria dos estudos se concentra nos praticantes do sexo masculino, enquanto as praticantes do sexo feminino frequentemente ficam em segundo plano (Graf & Fleischhacker, 2023).

Essa disparidade nas pesquisas reflete uma realidade mais ampla no mundo esportivo, onde o futebol masculino historicamente recebeu muito mais atenção, investimento e recursos do que o futebol feminino (Valenti et al., 2021). No entanto, à medida que a modalidade feminina ganha visibilidade e reconhecimento, merecidos,

parece ser fundamental abordar essa desigualdade, também, no campo da pesquisa científica.

A Agenda 2030 da Organização das Nações Unidas (ONU) é um marco significativo, em que definiu metas e objetivos globais para um futuro mais sustentável e igualitário (Assembly, 2015). Dois dos pilares fundamentais dessa agenda são a busca pela igualdade de gênero e a preocupação com as mudanças climáticas, incluindo o aquecimento global. É nesse contexto amplo e crucial que a presente tese de doutoramento se enquadra, isto porque estuda o efeito da exposição à temperatura ambiente elevada (38°C) em futebolistas do sexo feminino no desempenho físico e cognitivo (tema este que, até agora, permaneceu em grande parte não explorado).

O futebol é um esporte que demanda dos futebolistas um esforço intermitente, isso significa que ao longo de uma partida, os jogadores alternam entre momentos de alta intensidade, como sprints, dribles e disputas de bola, e períodos de menor atividade, como quando se estão reposicionando no campo (Dolci et al., 2020). Um protocolo intermitente que replica o esforço exigido de uma jogadora de futebol em campo oferece uma vantagem significativa ao proporcionar uma representação realista dos desafios enfrentados por essas atletas. Ao reproduzir a natureza intermitente do jogo, com variações na intensidade e nas pausas de esforço, esses protocolos permitem uma avaliação mais precisa do desempenho e das respostas físico-fisiológicas das jogadoras (Dellal et al., 2010).

Por outro lado, e também extremamente importante, a simulação em laboratório oferece um ambiente controlado e seguro, onde os pesquisadores podem monitorar de perto as atletas, garantindo segurança, reprodutibilidade dos estudos e fiabilidade dos resultados (Svensson & Drust, 2005), reduzindo significativamente o risco de exaustão por calor, desidratação e outros problemas de saúde relacionados ao calor (Svensson & Drust, 2005).

Para contextualizar a relevância deste estudo, é importante destacar a escassez alarmante de estudos que investigam o efeito da temperatura ambiente nos fatores físicos e cognitivos em futebolistas do sexo feminino. Esta lacuna de conhecimento se torna ainda mais evidente quando se trata de jogadoras de futebol de elite, cujas exigências e respostas podem diferir significativamente dos jogadores masculinos.

Neste sentido, a presente tese de doutoramento se apresenta como uma contribuição significativa para a ciência do esporte, para o avanço do futebol feminino e para a abordagem de temas científicos globais e urgentes a serem analisados. Esperamos

que nossas descobertas inspirem futuras pesquisas, orientem treinadores e profissionais da área científica e, o mais importante, habilitem as jogadoras de futebol a alcançarem seu potencial máximo em todas as condições ambientais a que estão sujeitas.

Face ao acima exposto, a presente tese de doutoramento teve como objetivo geral estudar o efeito da temperatura ambiente na performance física e antecipatória em futebolistas seniores femininas. Para se dar cumprimento ao anteriormente exposto, se definiram os seguintes objetivos específicos:

(i) Extrair e interpretar dados de estudos publicados que analisem o efeito da temperatura ambiente nas demandas físicas, fisiológicas e nos julgamentos antecipatórios de jogadores de futebol durante protocolos de indução de fadiga específicos para o futebol e, posteriormente, analisar, descrever e resumir as interpretações dos estudos elegíveis (Estudo I);

(ii) Desenvolver um estudo piloto que permita verificar o efeito de um protocolo laboratorial de exercício intermitente no desempenho da taxa de produção de força em jogadoras de elite do futebol português (Estudo II);

(iii) Analisar o efeito da temperatura ambiente nas habilidades físicas e antecipatórias em futebolistas do sexo feminino durante a realização de um protocolo de exercício intermitente (Estudo III).

Assim, considerando os objetivos anteriormente mencionados, espera-se encontrar, no primeiro estudo, pesquisas focadas nos impactos das temperaturas ambientais nas exigências físicas e nos julgamentos antecipatórios em jogadores e jogadoras de futebol durante protocolos específicos de indução de fadiga; no segundo estudo se espera que após a realização de um protocolo de exercício intermitente as jogadoras apresentem um decréscimo no desempenho do salto de contramovimento; e, por fim, no terceiro estudo se perspectiva que a exposição a temperaturas ambientais elevadas afetará negativa e significativamente o desempenho físico e antecipatório das futebolistas do sexo feminino após a realização de um protocolo de exercício intermitente, em comparação à exposição a temperatura ambiente amena,

A presente tese de doutoramento se encontra organizada em Introdução Geral, onde se introduz o tema em estudo, seu racional científico e se descreve os principais objetivos e respectivas hipóteses; os três capítulos (I, II e III) se apresentam estudos originais publicados em revistas científicas internacionais, com revisão de pares, de acordo com as suas normas de redação; de seguida, se apresenta a Discussão Geral, onde se debate conceptualmente as

diversas evidências científicas neste domínio; as conclusões finais da tese de doutoramento se encontram descritas na Conclusão; elencam-se nas referências bibliográficas a literatura consultada e utilizada na Introdução Geral e Discussão Geral; e, por fim, se apresentam os Anexos.

CAPÍTULO I

ESTUDO I

Effects of ambient temperature on physical and physiological demands and player's judgment ability assessed by a football-specific fatigue-inducing protocols: A systematic review
(*Journal of Human Sport & Exercise*, 2023, september. <https://doi.org/10.14198/jhse.2023.184.20>)

CAPÍTULO I

Estudo I- Effects of ambient temperature on physical and physiological demands and player's judgment ability assessed by a football-specific fatigue-inducing protocols: A systematic review

(Journal of Human Sport & Exercise, 2023, september. <https://doi.org/10.14198/jhse.2023.184.20>)

RUNNING HEAD: Effects of temperature in football players performance

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1.1 ABSTRACT

We systematically reviewed the effect of ambient temperature on football players' performance during a football-specific fatigue protocol. Data sources: Cochrane Library, PubMed, Scopus, SPORTDiscus, Web of Science. Eligibility criteria followed the P.I.C.O.S. approach: (i) Healthy football players regardless of sex, age, or competitive level; (ii) football-specific fatigue-inducing protocol followed by assessment of anticipatory judgments, under controlled temperature conditions; (iii) Comparison groups using a different temperature during the foot-ball-specific fatigue-inducing protocols; (iv) Outcomes included measures of anticipation, and/or physical or physiological tests; (v) No limitations regarding study design, if (ii) and (iii) were present. The searches resulted in 1,289 titles. However, none of the articles met the P.I.C.O.S. adopted, resulting in a total of zero eligible articles for the systematic review. Therefore, from a critical review of the existing literature, it must be concluded that evidence bases of sufficient scientific quality for the understanding the effect of temperature on physical and physiological demands and anticipatory judgments of football players is simply lacking. This should strongly motivate the scientific community to engage in research on the topic, to test if theoretical assumptions are accurate.

Keywords: Soccer; Decision-Making; Environment; Heat; Evaluation.

1.2 INTRODUCTION

Exposure to heat is a factor that can affect the performance of players who need to perform intermittent effort (Drust et al., 2000). Invasion field games, such as football, are characterized by intermittent activity profiles (Drust et al., 2000). Football match-play requires players to cover 10-12km (White et al., 2018) and perform a wide variety of activities ranging from walking to sprinting, with frequent and irregular intensity changes (Hamdan et al., 2022). Football simulation protocols aim to replicate the movement patterns and physiological demands of match-play (Drust et al., 2000; Nicholas et al., 2000; Russell et al., 2011; Thatcher et al., 2004), which is why researchers designed free running intermittent exercise protocols to simulate the activity pattern characteristics of football (Drust et al., 2000). However, several factors such as the omission of game specific skills (Russell et al., 2011), and the use of a non-grass surface might reduce the ecological validity of these protocols (Russell et al., 2011).

To cope with this limitation, modified protocols have been implemented to investigate football-specific skills (Ali et al., 2008; Foskett et al., 2009; Rostgaard et al., 2008), in which these protocols take into account that football requires mental concentration and situational-cognitive awareness to make the right tactical and technical decisions (Campo et al., 2011). Football is also cognitively demanding as it requires sustained attention to make quick, accurate decisions based on the retrieval and processing of information from a dynamic environment (Nédélec et al., 2012). These demands suggest that football may also be mentally fatiguing, with reductions in performance resulting from a combination of physical and mental fatigue. Successful football performance incorporates both physical and mental dimensions (Smith et al., 2016).

The ability to anticipate and make accurate decisions in a timely manner is fundamental to high-level performance in football (Williams et al., 2019). Decision-making is the ability to select and execute the appropriate action based on the current circumstances on the field of play, as well as the demands of the game strategically and tactically (Baker et al., 2003), which is considered essential in team sports, such as football (Gonzaga et al., 2014). For example, passing performance in football becomes important because an accurate pass may reach a teammate who is directly or indirectly unmarked and therefore create a chance to score a goal; it may also reach a teammate who is in the most advantageous position (Romeas et al., 2016). Considering the perceptual-cognitive processes underpinning decision-making (Casanova et al., 2013) and the amounts of information given to the athletes every moment, it is likely that football players may not make the best decisions if a perceptual-cognitive component is compromised (i.e. the athlete is mentally fatigued) (Gantois et al., 2020).

A key question for researchers, coaches, and practitioners is how to design practice activities and realistic environments so that athletes acquire and improve the ability to anticipate and make accurate decisions (Ford et al., 2019). For that to be possible, however, the relationships between certain environmental features, such as temperature, and performance require more investigation and investment, as well.

During some football competitions, such as the World Cup in Brazil in 2014 and the recent tournament in Qatar in 2022, players are forced to compete in hot and humid environments (Chmura et al., 2017; Sofotasiou et al., 2015), which, if hot enough and combined with high-intensity exercise, can lead the player to experience heat stress and

eventually hyperthermia (Meylan et al., 2021). Hyperthermia is characterized by an elevation in core (T_c) and skin temperature; an increase in sub-maximal exercise heart rate (HR); and, with subsequent dehydration, a reduction in peripheral blood flow and an eventual reduction in sweat rate, resulting in a decline in performance (Chalmers et al., 2014; Pryor et al., 2019; Racinais et al., 2015).

In this context, football is a sport with high physiological intensities that has the potential to result in greater heat-induced metabolic stress compared to other team sports (Chalmers et al., 2014; Datson et al., 2014). Previous research in high-level football players has shown how playing in temperature above 21°C and associated hyperthermia (Buchheit et al., 2011; Carling et al., 2011; Mara et al., 2015; Mohr et al., 2012) are negatively correlated to match performance resulting in a decrease in the total running distance covered, reduction of the high-intensity running speed, and the number of fast directional movements (acceleration and deceleration). Therefore, enhancing environmental preparation is required to optimize football performance in heat environments (Meylan et al., 2021).

Albeit some efforts were made to investigate the relationship between temperature and anticipation in sport, the results obtained from several studies were heterogeneous (Fortes et al., 2018; Gonzaga et al., 2014; Slattery et al., 2019) and considering the pattern established for the searches in the present study, 49 articles focused on some mutual themes proposed and were treated as systematic reviews. Some of studies have investigated the effects of acute exercise on cognitive performance (Chang et al., 2012), the impact of fluid consumption on athletic and cognitive performance (McCartney et al., 2017), the development of fatigue during a real football game (Silva et al., 2018), the different physiological markers of training load monitoring in football (Djaoui et al., 2017) and the effects of temperature and altitude on physical performance indicators in players during the game (Draper et al., 2022). However, none of them focused on football players or did not have heat as a research variable or did not use a football specific fatigue-inducing protocol.

There is a lack of systematic summary related to the effects of high temperature on anticipation judgments in players after football-specific fatigue-inducing protocol, in which this research might contribute to the construction of summarized knowledge in this specific domain. Therefore, a systematic review is pertinent to establish and detail objectively the overall body of knowledge and aggregate existing results in a coherent and informative way. The aim of this systematic review was to assess the literature that addressed the effect of

high temperature physical and physiological demands and anticipatory judgments of football players during a football-specific fatigue-inducing protocols.

1.3 MATERIALS AND METHODS

This systematic review followed the PRISMA 2020 guidelines (Page et al., 2021) (checklist presented in Supplementary material Table1) and Cochrane's guidelines (Higgins et al., 2019).

1.3.1 Eligibility Criteria

We included original research published in peer-reviewed journals, with no language limit. Eligibility criteria followed the P.I.C.O.S. approach: (i) Healthy football players with no restrictions concerning sex, age, or competitive level; (ii) Studies using football-specific fatigue-inducing protocols followed by assessment of anticipatory judgments using temporal and/or spatial occlusion paradigm (e.g., response accuracy, reaction time, movement time), under controlled temperature conditions; (iii) Comparison groups were the same as the intervention, but using a different temperature during a football-specific fatigue-inducing protocols; (iv) Outcomes included measures of anticipation (i.e., response accuracy, reaction time, movement time), and/or physical or physiological tests (e.g., 1 repetition maximum strength test, salivary stress biomarkers); (v) No limitations regarding study design, as long as two groups exposed to different temperatures were present.

1.3.2 Information Sources

Searches were performed on December 16th of 2022. In the following databases: Cochrane Library, PubMed, Scopus, SPORTDiscus and Web of Science. Subsequently, without applying filters. Two external experts (Ph.D., published research on the topic through many publications on the Web of Science) were consulted to provide further suggestions of potentially relevant studies. Following the recommendations of Higgins et al. (2019), a final search was carried out for errata and retractions of the included studies. In case there were pre-registered protocols and/or complementary files of the included studies, these were also retrieved.

1.3.3 Search Strategy

The general search strategy made use of free text terms and the Boolean operators AND/OR, with four lines of code being implemented in all fields/all text/full text:

(Soccer OR Football) AND (Anticipat* OR Judg* OR Decision* OR Percept* OR cogniti*) AND (Temperature OR cold OR heat*)*

The full search strategies for each database are presented in Table 1.

Table 1. Full search strategies for each database.

Database	Search strategy
Cochrane Library	Soccer OR Football* in Title Abstract Keyword AND Anticipat* OR Judg* OR Decision* OR Percept* OR cogniti* in Title Abstract Keyword AND Temperature OR cold OR heat* in All Text - (Word variations have been searched)
PubMed	((Soccer [Title/Abstract] OR Football*[Title/Abstract]) AND (Anticipat*[Title/Abstract] OR Judg*[Title/Abstract] OR Decision*[Title/Abstract] OR Percept*[Title/Abstract] OR cogniti*[Title/Abstract])) AND (Temperature OR cold OR heat*))
Scopus	(TITLE-ABS-KEY (soccer OR football*) AND TITLE-ABS-KEY (anticipat* OR judg* OR decision* OR percept* OR cogniti*) AND ALL (temperature OR cold OR heat*))
SPORTDiscus	Title/Title/Text “TI (Soccer* OR “Anticipat*” OR “Judg*” OR “Decision*” OR “Percept*” OR “cogniti*” OR “cold*” OR “Temperature*” OR “heat*”) AND TI (Football* OR “Anticipat*” OR “Judg*” OR “Decision*” OR “Percept*” OR “cogniti*” OR “cold*” OR “Temperature*” OR “heat*”) AND TX (Soccer* OR Football* “Anticipat*” OR “Judg*” OR “Decision*” OR “Percept*” OR “cogniti*” OR “cold*” OR “Temperature*” OR “heat*”)” Abstract/Title/Text “AB (Soccer* OR Football* “Anticipat*” OR “Judg*” OR “Decision*” OR “Percept*” OR “cogniti*” OR “cold*” OR “Temperature*” OR “heat*”) TI (Soccer* OR “Anticipat*” OR “Judg*” OR “Decision*” OR “Percept*” OR “cogniti*” OR “cold*” OR “Temperature*” OR “heat*”) AND TI (Football* OR “Anticipat*” OR “Judg*” OR “Decision*” OR “Percept*” OR “cogniti*” OR “cold*” OR “Temperature*” OR “heat*”) AND TX (Soccer* OR Football* “Anticipat*” OR “Judg*” OR “Decision*” OR “Percept*” OR “cogniti*” OR “cold*” OR “Temperature*” OR “heat*”)”
Web of Science	ALL FIELDS: (Soccer OR Football*) TOPIC: Anticipat* OR Judg* OR Decision* OR Percept* OR cogniti*) AND ALL FIELDS: (Temperature OR cold OR heat*)

1.3.4 Selection Process

AP and EC independently screened each record and each report retrieved. In case of disagreements between the two authors, JA provided arbitrage until consensus was achieved.

Automated removal of duplicates was performed using EndNoteX9, but further manual removal of duplicates was required.

1.3.5 Data Collection Process

AP and EC independently collected data from reports. In case of disagreements between the two authors, JA provided arbitrage until consensus was achieved. In case of relevant data being missing and/or additional details being required, the authors of the studies were contacted at least two times, and the required information were solicited. No automation tools were used.

1.3.6 Data Items

Outcomes: Anticipation assessment using at least one of the following outcomes-temporal and/or spatial occlusion paradigm (e.g., response accuracy, reaction time, movement time); Physical tests (e.g., countermovement-jump, football-specific fatigue-inducing protocols); Physiological tests (e.g., salivary stress biomarkers).

Additional variables: participant-related characteristics (e.g., sample size, sex, competitive level, exposure to different temperatures, exposure to regular sports training), assessment-related features (e.g., specific assessments that were performed, number and blinding of testers, familiarization with testing procedures, time of season during the assessments, reliability of the assessments), adverse events, and other study-related information (e.g., country, funding, competing interests).

1.3.7 Risk of bias in studies, effect measures, data synthesis and certainty of evidence

The risk of bias of individual studies, planned effect measures, data synthesis and certainty of evidence can be consulted in the pre-registered protocol (<https://osf.io/qkeas/>). Due to a lack of studies fulfilling the eligibility criteria, these steps were not implemented.

1.4 RESULTS

1.4.1 Study Selection

An initial search returned 1,289 results (Cochrane Library: 1; EBSCO: 530; PubMed: 69; Scopus: 513; and Web of Science: 176). After removing duplicates, 652 records remained. Screening titles and abstracts for eligibility criteria resulted in the exclusion of

637 records, 71 were excluded because they were not empirical studies published in peer-reviewed journals. However, no studies were identified that met the P.I.C.O.S. adopted in this systematic review (Figure 1). As such, we were not able to perform the meta-analysis initially proposed in our project (<https://osf.io/qkeas/>) nor any narrative synthesis. Two external experts (Ph.D., published research on the topic through many publications on the Web of Science) were asked to indicate probable studies that respect the P.I.C.O.S. established, but their responses resulted in no additional study fulfilling the eligibility criteria.

1.4.2 Study characteristics

No studies met the inclusion criteria for this review; this was largely attributed to the fact that no study has evaluated at least two groups of football players exposed to different temperatures (i.e., heat and on ambient temperature) when simultaneously performed a football-specific protocol to induce physical and physiological fatigue and assessing the judgment ability. Particularly, in the present systematic review, few studies were found that proposed to evaluate the effect of heat on players (Duffield et al., 2013; Duffield et al., 2012), but some of them did not use a football-specific fatigue-inducing protocol (Guttierres et al., 2011; Meylan et al., 2021). Other studies found assessed the effect of heat on physical and physiological capacities (Bandelow et al., 2010; Yeargin et al., 2010). There were studies that proposed to evaluate the effect of heat on physical and physiological indicators, including the players' judgments, but the players were not evaluated at a control room temperature (Ernwein et al., 1998; Greig et al., 2007).

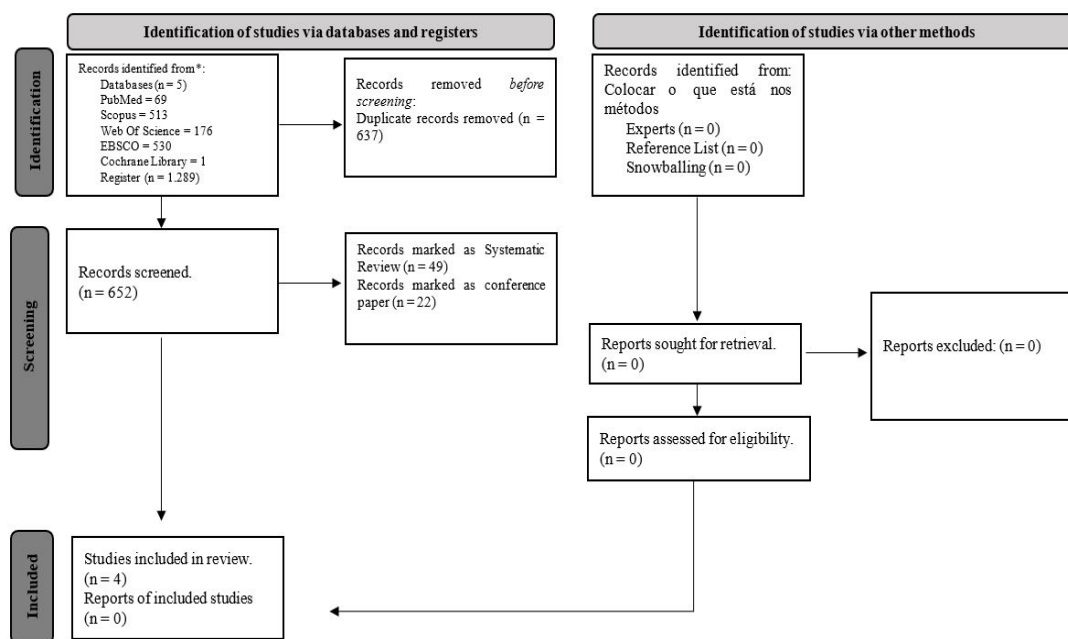


Figure 1. PRISMA flow diagram highlighting the selection process for the studies included in the systematic review.

1.5 DISCUSSION

The aim of the present systematic review was to establish and detail current literature focusing on the effects of high temperature in physical and physiological demands and anticipatory judgments of football players during a football-specific fatigue-inducing protocols. From the literature search, no studies met the P.I.C.O.S. criteria that was adopted in this systematic review, with all studies failed to provide evidence on the effects of different temperatures (i.e., heat and on ambient temperature) in physical, physiological and judgment abilities on football during a football-specific protocol.

In recent years, two FIFA World Cups were held in countries where a predominance of hot weather during the competition was observed (Brazil 2014 and Qatar 2022). These environmental conditions caught the attention of the scientific community (Assembly, 2015), which was concerned with investigating in a deeper way the risks that players might be expose to this adverse condition. A football-specific fatigue-inducing protocol allows the researcher to simulate the effects that the player suffers in a football match in a laboratory environment (Drust et al., 2000), since heat becomes a variable of great importance to be currently analyzed.

At the present, few researchers have studied the influence of temperature in physical and decisional performance on football players (Benjamin et al., 2021; Clarke et al., 2011;

Coull et al., 2015; Edwards et al., 2007). Moreover, it is important to suggest that future studies must have the assumption of helping the sports community to improve and to evolve the football.

Four studies were closest to the P.I.C.O.S. criteria, but as previously mentioned, none of them addressed all the criteria adopted in this systematic review (Benjamin et al., 2021; Clarke et al., 2011; Coull et al., 2015; Edwards et al., 2007). Particularly, in these four studies we methodological detected that the effect of heat on performance was analyzed without using a control group exposing and comparing their performance to different temperatures, which lead to heterogeneous and dissimilar results. For example, the study conducted by Clarke et al. (2011) aimed to examine the effect of carbohydrate ingestion and pre-cooling on the physiological responses of 12 players using a football-specific intermittent exercise and the impact on subsequent high-intensity exercise performance in the heat. The results obtained must be questioned since the changes in physical and mental performance were only provoked by the exposure of hot conditions or by the protocol itself.

Another critical point detected in some of the studies excluded from the present systematic review was about the sample size, particularly the subjects used in the experimental studies consisted in a range of 8 (Coull et al., 2015) and 12 football players (Benjamin et al., 2021; Clarke et al., 2011; Edwards et al., 2007). We considered that small sample could be insufficient to present any robust conclusion that may guide the scientific and sports community. Additionally, we observed that only one study (Coull et al., 2015) implemented a protocol familiarization procedure to the subjects tested, which concerned us about the reliability of the results obtained by the other studies mentioned (Coull et al., 2015; Edwards et al., 2007). Moreover, in all these four studies (Benjamin et al., 2021; Clarke et al., 2011; Coull et al., 2015; Edwards et al., 2007), the physiological variables collected (e.g., HR, level of dehydration and body temperature) in football players were conducted using different procedures, which lead us to observe heterogeneous results in all of them.

Due to these issues, the literature to date has considerable inconsistencies in the experimental conditions and in evaluating all the variables separately or combined, which has likely contributed to the poor understanding of this phenomenon. In addition, the literature is lacking in terms of the effects that the heat would have on the physical, physiological and on male or female football players' judgments during a football-specific fatigue-inducing protocol.

Therefore, we end up with an empty review (Lang et al., 2007; Yaffe et al., 2012). Globally, it is relevant to science that all data be published to provide a more balanced explanation of the topics being studied (Weintraub, 2016). Specifically, empty reviews are relevant and useful for the advancement of evidence-based practices, highlighting major research gaps (Lang et al., 2007; Weintraub, 2016; Yaffe et al., 2012).

1.6 CONCLUSIONS

The lack of publications related to this topic is in direct contrast with the importance given by the scientific community to the effects of heat on football players. The physical and physiological demands and player's judgment ability are fundamental factors in their performance throughout the game, especially when they are exposed to high temperatures. Unlike studies that evaluate these three variables separately, it is mandatory to evaluate all of them combined. Therefore, the diagnosis we can reach at the end of this systematic review is that there is still a gap in the literature on this topic, where other studies can contribute to increasing knowledge about athletes, not only with male, but also with female participants.

Future recommendations

Having confirmed that there are no studies to date that assess the effect that a football specific fatigue-inducing protocol has on the physical and physiological demands and players' judgments about the influence of heat, the present study contributes by pointing to this gap in the literature on the subject and reaffirming the importance of future studies should be carried out exposing male and/or female players to this type of condition and also more representative evaluative tasks in relation to the context of football is needed. Moreover, the findings of the present study as an empty review must be carefully attended by researchers given them clear instructions for the incorporation of potentially important information not always considered in systematic reviews of interventions, as well as specific direction on whether to discuss and how to present the findings of non-included studies.

Limitations

The limitations found in this systematic review were that no studies have been reported that focus on the impact of heat using football-specific fatigue-inducing protocols. The studies found related to heat carried out their collection in an external environment and always in the summer period, that is, there was no control of the ambient temperature or the humidity that the players were exposed to. In this systematic review, no studies were found

that compared a control group with another group exposed to heat. The fact that the result was a total of zero articles found in the P.I.C.O.S. adopted prevented the performance of a meta-analysis.

AUTHOR CONTRIBUTIONS

Alberto Pompeo, research concept and study design, literature review, data collection, data analysis and interpretation. Everton Luis Rodrigues Cirillo: data collection and data analysis and interpretation. Júlio Alejandro Henriques da Costa: writing the manuscript or reviewing/editing a draft of the manuscript. José Vilaça-Alves: writing the manuscript or reviewing/editing a draft of the manuscript. Andrew Mark Williams: research concept, writing the manuscript, or reviewing/editing a draft of the manuscript. Rodrigo Ramirez-Campillo: data analysis and interpretation and statistical analyses. José Afonso: data collection, data analysis and interpretation, statistical analyses and reviewing/editing a draft of the manuscript. Filipe Casanova: research concept and study design, literature review, writing the manuscript, or reviewing/editing a draft of the manuscript.

SUPPORTING AGENCIES

No funding agencies were reported by the author.

DISCLOSURE STATEMENT

No potential conflict of interest was reported by the author.

OTHER INFORMATION

This systematic review was registered on the OSF platform under the OSF registration number of January 20th of 2022. Link to the project: OSF registration <https://osf.io/qkeas/>. Link for registration: <https://osf.io/p4fz8>. It was also followed the PRISMA 2020 recommendations (Page et al., 2021) and Cochrane's guidelines (Higgins et al., 2019).

ACKNOWLEDGMENTS

The authors thank all participants involved in this study and appreciate the collaboration of the authors of the studies involved in this research, where they spared no

effort in providing documents and data that enriched this research. We also thank the experts PS and PE for their willingness to suggest studies for this research.

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CAPÍTULO II

ESTUDO II

The effect of an intermittent protocol on strength performance in female football players: an exploratory study

(Motricidade, 2023, 19(2), 211-216. <https://doi.org/10.6063/motricidade.32173>)

CAPÍTULO II

Estudo II - The effect of an intermittent protocol on strength performance in female football players: an exploratory study

(Motricidade, 2023, 19(2), 211-216. <https://doi.org/10.6063/motricidade.32173>)

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2.1 ABSTRACT

Football is a sport that involves a combination of continuous and intermittent effort. Therefore, players need to be able to recover quickly between moments of high intensity to continue to perform at a high level of output throughout the entire match. The present study aimed to evaluate the effect of an intermittent exercise protocol on the rate of high-intensive force production through the countermovement test (CMJ) in elite Portuguese female soccer players. The sample consisted of 12 players from the first division of women's football in Portugal (Age = 18.1 ± 0.9 years; Weight = 60.10 ± 5.8 Kg; Height = 1.63 ± 4.8 cm; BMI = 22.48 ± 1.5 kg/m²). The players performed an intermittent exercise protocol on a cycle ergometer, lasting 8 minutes, in which each minute corresponded to 40 seconds of high-intensity (4W/kg, based on the player's body weight) and 20 seconds of low-intensity (75W). Before and after the protocol, the players performed the CMJ. Through the results obtained, it was possible to observe that players presented a significant decrease in the height of the CMJ between the two moments (before- 29.92 ± 3.55 cm vs after- 26.92 ± 4.05 cm; $p < 0.01$). The present study allowed us to conclude that intermittent exercise protocol promoted a negative influence on CMJ performance.

Keywords: Soccer; Fatigue; Evaluation; Laboratory; Countermovement Jump.

2.2 INTRODUCTION

Achieving high performance in football athletes is a permanent quest and a constant challenge for the sports science community, who are involved with improving athletic fitness. Like what happens in several collective sports, football has also evolved thanks to the participation of sport sciences (Raya-Castellano & Uriondo, 2015).

Therefore, as a result of football involvement, the entire activity underwent and continues to undergo greater and more detailed knowledge of the player, with clear repercussions on the improvement of their level of athletic aptitude for the competitive practice of football (Raya-Castellano et al., 2015).

Football is a game of cooperation and opposition between players and teams, which results in complex and unpredictable dynamics (da Silva, 1998). During official games and training sessions, players perform an intermittent effort, where they are exposed to varied

physical demands, including races, jumps, sprints, accelerations, decelerations and constant changes of direction, requiring strength and power of lower limbs (Stølen et al., 2005).

The continuous production and loss of strength throughout the match generate physical exhaustion (Reilly et al., 2008). As the game progresses, energy levels decline, and fatigue builds up in the muscles, reducing force output and the players' ability to perform these actions with equal efficiency (Reilly et al., 2008). This loss in the effectiveness of movements may result from the player's loss of strength and power, which may affect his performance over 90 minutes of the game (Turner & Stewart, 2014). Some researchers applied jumping tests to assess the muscle power of the lower limbs in football players, for example, the counter-movement jump (CMJ) is largely used (Jiménez-Reyes et al., 2017).

Concurrently, women's football is continually developing, and the game itself demands greater physical capacity from female players (Scott & Bradley, 2020). In the last two editions of the Women's World Cup (i.e., Canada- 2015, and France- 2019), players had a higher average speed and covered greater distances during matches (cf., Scott & Bradley, 2020). These recent findings may suggest that the scientific community must carry out studies on female players to ultimately understand their needs and evolution.

The methods that can be used in competition to determine the physiological stresses associated with match-play are limited (Brownstein et al., 2017). The demands of match-play have been examined by observing matches, obtaining physiological measures during real and simulated games, and determining the physical capacity of elite players on performance tests (Drust et al., 2000). Such information is not always associated with the controlled conditions found in experimental investigations or subject to the depth and accuracy of laboratory-based analysis (Drust et al., 2000).

Several researchers have devised laboratory-based exercise protocols to assess the physiological and metabolic responses to intermittent exercise (Balsom et al., 1992), allowing greater robustness in the results obtained (Lemmink & Visscher, 2005). Therefore, Lemmink and Visscher (2005) validated an intermittent exercise protocol on a cycle ergometer for football players. This intermittent protocol is performed on a cycle ergometer and lasts 8 minutes, each minute corresponding to 40 seconds of high-intensity (4W/kg, based on the player's body weight) and 20 seconds of low-intensity (75W).

The protocol abovementioned can bring the advantage of stimulating the anaerobic system, which is essential for bursts of speed and high-intensity efforts in football (Strudwick & Iaia, 2018), increasing their ability to produce energy quickly without relying solely on oxygen supply (Strudwick & Iaia, 2018). Using a cycle ergometer protocol is also a low-impact form of exercise, which means that it causes less stress on the joints, preserving the player's physical integrity (Werstein & Lund, 2012). However, it must be addressed that this protocol may not perfectly replicate the movement patterns and the real physical demands found during a football match, generating a lack of specific neuromuscular stimulus (Werstein & Lund, 2012).

Studies conducted using female football players are necessarily increasing since women's football has been developing more and more, attracting the attention of fans and the media (Vezzali et al., 2023). Therefore, the present study aimed to analyse the effect of an intermittent exercise protocol on strength performance in female Portuguese football elite players. Moreover, we expected female players to perform worse in the countermovement jump results after performing an intermittent exercise protocol.

2.3 METHODS

2.3.1 Sample

Twelve elite female football players from the Portuguese First Division were recruited to participate in the present study (Age = $18,1 \pm 0,9$ years; Weight = $60,10 \pm 5,8$ Kg; Height = $1,63 \pm 4,8$ cm; BMI = $22,48 \pm 1,5$ Kg/m²). The participants played in the Portuguese Premier League, and all of them played for their national teams (Portugal and Brazil). The G*Power version 3.1.9.7 was used to calculate the sample size, and a minimum of 12 players were required ($f^2 = 1.1$, $\alpha = 0.05$, and $\beta = 0.96$) (Verma & Verma, 2020).

The players had their anthropometric data collected before the protocol was initiated, namely: height (Seca 213 portable stadiometer, Seca, Hamburg, Germany), weight and body mass index (BMI) (Omron Body Composition Monitor BF511, Omron, Kyoto, Japan). The procedures were presented to the participants, who then provided informed consent. The study was approved by the Ethics Committee of the host university (protocol number M25A21), and all procedures were conducted in accordance with the Declaration of Helsinki

2.3.2 Procedures

2.3.2.1 Intermittent Exercise Protocol (Lemmink & Visscher, 2005)

The players performed an intermittent exercises protocol validated for football players by Lemmink and Visscher (2005). The height and saddle distance of the computer-controlled stationary bicycle (SRM Ergometer, Schoberer Rad Meßtechnik, Jülich, Germany) were standardised for each participant. Based on the players' body mass, the high-intensity loads (4 W/kg) were calculated and, together with the low-intensity loads (75 W), imported into the computer. The use of a personal cycle protocol related to body mass aimed at comparable intensity among participants. After 2 min of warm-up at 75 Watts (W), each player performed it for a total duration of 8 min, divided into 8 blocks of intermittent exercise (each block had 1 min). In each block, players alternated high-intensity exercise at 4 W/kg for 40 seconds and low-intensity exercise at 75 W for 20 seconds. During the first 15 seconds, both in periods of high-intensity (4 W/kg) and periods of low-intensity (75 W), the workload was permanently changed continuously to avoid abrupt transitions between exchanges of workload across the protocol. At the end of the 8 minutes of protocol, a cooling of 1 min at 75 W was performed.

The players were instructed throughout the test to maintain the cycling frequency between 70 and 80 rotations per minute (RPM). Exercise workloads were recorded using heart rate (HR) in 5-sec interval short-range telemetry (DUAL ANT+, Bluetooth Smart running heart rate monitor, SRM, Jülich, Germany). To obtain the HRmax of each player, the formula proposed by Alder et al. (2021) was used ($HR_{max} = 220 - Age$).

To assess the maximum height of the players, the CMJ was immediately collected at the beginning and at the end of the protocol (or where the participants could sustain the effort) using the Optojump (Optojump Photocell System, Microgate, New York, USA). The Optojump is an optical measuring system which can be used for vertical jump height measurement. It consists of two bars, a transmit and a receive bar, each measuring 39.4x1.2x1.6 inches and containing between 33 and 100 LEDs. This tool allows the measurement of all jumps performed by the players in centimetres (cm). Each player performed three successful CMJs with hands on her hips from a standing position. Rest periods of half a minute between the jumps were assumed. Additionally, players were instructed to jump as high as possible and pose with both feet (cf., Jiménez-Reyes et al., 2017).

The players performed the intermittent protocol and the CMJ once to familiarise themselves with the task, and after a week's interval, the data was collected.

2.3.2.2 Statistical Procedures

The distribution of data sets was analysed using Shapiro-Wilk tests, and the values obtained were expressed as mean $\pm$ SD and 95% confidence intervals (CI). The Paired T-Test was used to compare the CMJ values obtained before and after the protocol (Ross et al., 2017). The statistical software used was “SPSS for Windows 20.0”. The alpha level for significance was set at $p < 0.05$ and the value of t (5.911).

2.4 RESULTS

During the execution of the protocol, several football players reached a significant level of intensity, reaching 90% of their HRmax. Moreover, in less than a minute, the players showed an increase in their HR, surpassing 80% of their maximum capacity. The elevated HR values were maintained throughout the remainder of the protocol (Figure 1).

The CMJ values obtained after and before the protocol intervention are presented in Table 1.

Table 1– Mean ($m \pm SD$) values of Countermovement jump (CMJ) before and after the intermittent protocol.

	Before Protocol ($m \pm SD$)	After Protocol ($m \pm SD$)	p
CMJ (cm)	29,92 $\pm$ 3,55	26,92 $\pm$ 4,05	0.000

According to the results obtained, the female players had a lower performance in the CMJ performed after the protocol (26.92 $\pm$ 4.05 cm) compared to the jump performed before the protocol (29.92 $\pm$ 3.55cm).

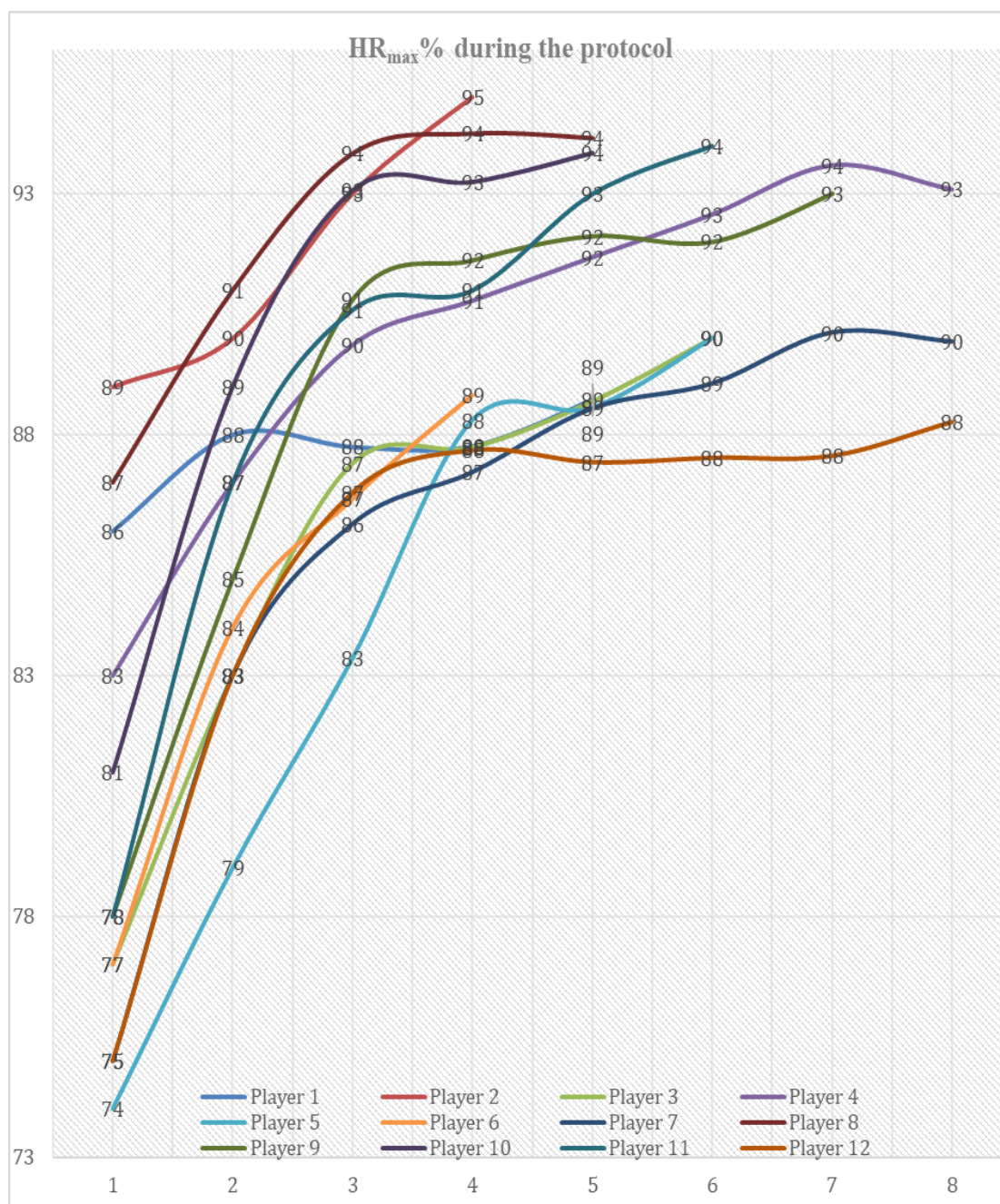


Figure 1- Percentage of HR_{max} (% HR_{max}; Y-Axis) of female players (X-Axis) during the intermittent protocol.

2.5 DISCUSSION

Intermittent exercise is a strategy commonly used in football training, both for men and women, aiming to improve athletes' aerobic and anaerobic capacity (Gabbett & Mulvey, 2008). However, it is important to investigate the effects of intermittent effort on female football players. Therefore, the present study aimed to analyse the effect of an intermittent exercise protocol on strength performance in female Portuguese football elite players. As

expected, the results confirmed that the intermittent exercise protocol proposed by Lemmink and Visscher (2005) negatively affected the CMJ performance in female football players.

The rapid increase in HR values along the protocol suggested that the exercise was challenging the players' cardiovascular system, requiring considerable effort to sustain the required intensity (Marcora et al., 2008). Moreover, the intensity and physical demands required by the protocol may have been too excessive for players 1, 2, 5, 6, 8, 9, 10 and 11 (Figure 1), resulting in withdrawals during the activity. The female players who were able to complete the protocol maintained their HR at 85% of their HR max from the fourth minute of the protocol, which is considered to be a high-intensity workload (Marcora et al., 2008).

The strength ability is fundamental to compete effectively in game situations that involve ball disputes in the air, such as headers and interceptions, both in attack and defence (Jiménez-Reyes et al., 2017). That is why the researchers used valid and reproducible tests that may assess this particular ability, like CMJ (Morcillo et al., 2015).

Our findings showed a significant decrease in the CMJ performance of female players ($p < 0.01$) due to intermittent effort applied by the intermittent protocol. The CMJ performance requires a quick and high intensive production of muscle strength to propel the body into the air (Pedley et al., 2017), and this ability was impaired by the intermittent protocol implemented. It is important to notice that CMJ is a movement that requires a combination of strength, speed, and muscle power to produce an efficient jump (Sporiš et al., 2010), and when there is a loss of muscle strength due to physical wear during a match or after an intense exercise protocol, like our players, the ability to produce the necessary strength for jumping can be compromised (Pedley et al., 2017).

Although this kind of experiment has not been carried out with female football players, some studies evaluated the influence of fatigue-inducing protocol on the strength production capacity of a football player. Morcillo et al. (2015) used the CMJ as a tool to analyse the relationships between repeated sprint ability, mechanical parameters and metabolites in 18 professional male football players in Spain. Torreblanca-Martinez et al. (2017) evaluated the effects that a fatigue-inducing protocol generated on the kick of 15 U-18 male football players from a professional club, using the CMJ as an assessment tool. Both studies reported that after the fatigue induction protocol, players lost the ability to generate maximum strength, which was pointed out as one of the reasons for the loss of players' performance.

In addition, the loss of muscle strength can decrease the speed and muscle power of the player, directly influencing the performance in the CMJ (Loturco et al., 2019). McFarland et al. (2016) analysed CMJ performance after repeated sprints and change of direction in 20 male and 16 female NCAA Division II players, and their results evidenced that players lost execution speed and worsened their CMJ performance after testing, suggesting that physical exhaustion generated by the intermittent protocol may have generated peripheral muscle fatigue, and inhibited the muscles to maintain the expected performance (Marcora et al., 2008).

2.6 CONCLUSIONS

The present study suggests that intermittent exercise protocol used negatively affects female football players' strength performance. Moreover, the used intermittent protocol enhanced peripheral fatigue like those found during high intensity periods of a football match.

2.7 FUTURE SUGGESTIONS

The intermittent protocol can simulate fatigue situations like those found during a football match. This challenges players to maintain high-quality performance even when they are tired. This coaching approach can help improve players' ability to make quick decisions. Laboratory studies allow us to obtain more robust scientific results and increase player safety throughout the testing sessions. Therefore, we pointed out some other research questions that the community should study, particularly: What would be the effect of high temperature on female football players during an intermittent protocol that can simulate a match? How could this affect the physical, physiological and, especially, cognitive demands?

It is essential for the scientific community to develop studies that can provide tools to help the football staff identify and overcome possible underlying causes of performance loss by female players, optimising their ability to perform their skills within the game.

2.8 ACKNOWLEDGEMENT

To the participants and all staff of Jamor High-Performance Center.

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CAPÍTULO III

ESTUDO III

Impact of temperature on physical and cognitive performance in elite female football players during intermittent exercise

(Scandinavian Journal of Medicine and Science in Sports, 22 April 2024, DOI: 10.1111/sms.14646)

CAPÍTULO III

Impact of temperature on physical and cognitive performance in elite female football players during intermittent exercise (Received: 22 January 2024 Revised: 22 March 2024; Accepted: 22 April 2024; Scandinavian Journal of Medicine and Science in Sports)

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3.1 ABSTRACT

There is limited research on female football players, especially related to their physical and cognitive performance under different climactic conditions. We analysed the impact of a hot environmental temperature on physical performance and anticipation in elite female football players during a fatigue-inducing intermittent protocol. Elite female players ($n=21$) performed the countermovement jump (CMJ) and responded to filmed sequences of offensive play under two distinct environmental temperatures (i.e., mild environment temperature- 20° C and 30% rh vs hot environment temperature- 38°C and 80% rh), interspersed by 1-week interval. Linear Mixed Models were used. CMJ performance declined following the intermittent protocol on both temperature conditions ($p<0.05$). Moreover, there were significant main effects for protocol on CMJ speed (m/s) ($p = 0.001$; $\eta_p^2 = 0.12$), CMJ power ($p = 0.002$; $\eta_p^2 = 0.11$), and CMJ Height_{max} ($p=0.002$; $\eta_p^2 = 0.12$). After performing the intermittent protocol, exposure to a hot temperature caused a greater decline in anticipation accuracy (mild temperature = 64.41% vs hot temperature = 53.44%; $p<0.001$). Our study shows impaired performance in elite female football players following an intermittent protocol under hot compared with mild environmental conditions. We report decreased performance in both CMJ and anticipation performance under hotter conditions. The results reveal that exposure to hot temperatures had a negative effect on the accuracy of their anticipatory behaviours. We consider the implication of the work for research and training interventions.

Keywords: Soccer; Women; Hot Environment; Physical Performance; Anticipation; Fatigue.

3.2 INTRODUCTION

The importance of climate change and environmental diversity on players physical¹ and perceptual-cognitive^{2, 3} performance is well-reported. For example, during the 2014 FIFA World the weather in Brazil became a major concern for many football teams since, under thermal stress, running and jumping abilities are compromised to a greater extent than under temperate conditions⁴. Several international federations, including FIFA, responded to the International Olympic Committee's call to create a surveillance system to assess environmental conditions and their adverse outcomes during competition⁵. According to Wet-Bulb Globe Temperature Risk Chart⁶ mild and hot environment temperature conditions are classified as 18°C - 23°C and > 28°C, respectively. Regardless, major competitions continue to be scheduled in equatorial or Middle Eastern regions (e.g., the 2022 Qatar Football World Cup) that still present challenges in preventing injury and illness in athletes. Also, as physical exhaustion increases in adverse weather conditions, such conditions may impact cognitive function including anticipation and decision-making⁷.

Published reports highlight that extreme environmental conditions impact body homeostasis, promoting dehydration, thermal stress and affecting body temperature and player performance^{8, 9}. During exercise, behavioural mechanisms may adjust and regulate according to environmental conditions and through duration and/or intensity¹⁰. In addition, researchers have shown that exercise performed at a hot environment temperature and high relative humidity (e.g. 35°C and 80%rh) causes the body to produce more sweat to dissipate heat, increasing the body's demand to maintain an adequate core temperature¹¹.

These effects may impair cognitive performance, even at moderate exercise intensities¹². Unsurprisingly, exposure to a hot environmental temperature impairs soccer-specific decision-making². Moreover, there have been some attempts to study how anticipation is affected by increasing physical and physiological demands¹³. Physiological workload and the tactical expertise of football players have been shown to interact, impacting perceptual-cognitive function (e.g., visual search behaviour) in game situations. The ability to recognize and anticipate what an opponent will do next and to execute the most appropriate decision are important components of performance in football¹⁴. The ability of players to anticipate quickly and accurately relies on the development of domain-specific perceptual-cognitive skills that interact dynamically³. It is not well-reported how

physical exhaustion³ and/or environmental temperature² impact on these cognitive functions.

The skilled performer's ability to cope with stressors, such as fatigue and hot environment temperatures, could determine how these skills are executed in extreme match situations. It is well established that a hot environmental temperature significantly influences physical and physiological variables¹⁵, dehydration levels, autonomic nervous system assessed throughout heart rate variability (HRV) indices¹⁶, muscle strength loss and power¹⁷, and decision accuracy^{2, 18}. In contrast, the exercise-cognition interaction in high-demanding physiological and thermal environments has not been well-documented^{2,3}. Scientists have proposed an inverted-U relationship between exercise intensity and cognitive performance¹⁹, with moderate- and high-intensity exercise increasing and impairing performance, respectively. Similarly, Attentional Control Theory (ACT)²⁰ was proposed to clarify how attentional resources and subsequent performances are influenced under increasing levels of stress during performers. Mental fatigue can lead to further reductions in tactical performance²⁰ and it has been shown to impair technical skill execution²¹, both are important components of intermittent sports performance^{22, 23} and key predictors of success^{24, 25}. These cognitive impairments have the potential to threaten the health and performance of athletes in competition and increase the risk of injury²⁶, particularly in a sport where complex tactical decision-making and the technical execution of skills have a large influence on match outcomes²⁷.

Previous reports have highlighted methodological shortcomings pertaining to measurement sensitivity, poor research design and lack of experimental control²⁸. Generally, studies conducted in laboratory environments are more suitable for reliable assessment of player performance under different temperature conditions, while improving the safety of the participants²⁹, and helping the research community to better understand the interaction between laboratory and real-field contexts^{30, 31}. Moreover, some instruments, like cycle ergometers have been commonly used when field measures are unavailable, or for the measurement of variables that are difficult to implement in the field (power, force and speed profiling)³². In this vein, an intermittent exercise protocol was validated for football players, which reproduced the maximal physical effort during the match³³.

Previous attempts to research this phenomenon in football have mostly been limited to male players³⁴⁻³⁷. Yet, researchers have shown that men and women present different

physiological responses to exercise under hot environment temperatures^{38, 39}, although it is unclear to what extent these differences impact sports-specific performance. Additionally, global warming and gender equality have become priority areas on the United Nations agenda⁴⁰. In this context, studies that evaluate the effects of hot environments on female players are of great importance for the football community, particularly given the notable absence of previous work on this topic⁴¹. Although some attempts have been reported that evaluate the effects of fatigue on the physical capacities of female football players^{42, 43}, and the effect of fatigue on the mental capacities of the players⁴⁴, further efforts are needed to evaluate the physical and cognitive performance of female football players.

The present study was designed to assess the impact of exposure to hot environmental temperatures on the physical and perceptual-cognitive performance of female football players using a laboratory-based intermittent protocol. This approach addresses a relevant gap in the literature combining an intermittent exercise protocol, realistic film-based simulations of offensive sequences of play, and physical performance measures of female football players under controlled temperature conditions (i.e., mild environment temperature- 20° C and 30% rh, and hot environment temperature- 38°C and 80% rh). We assess physical performance using CMJ (i.e., maximum height, strength, power, and speed), and perceptual-cognitive performance using a soccer-specific, film-based task that require players to anticipate what will happen next. Based on previous research highlighting the detrimental effects of workload on physical² performance and anticipation³ in male players, we hypothesized that CMJ and anticipatory performance of female players would decrease after an intermittent exercise protocol, regardless of the temperature exposure. We expected a decline in the anticipatory performance of female football players in response to hot environment temperature.

3.3 MATERIAL AND METHODS

3.3.1 Subjects

The G*Power version 3.1.9.7 was used to calculate sample size and a minimum of 21 players were required ($f^2 = 0.91$, $\alpha = 0.05$, and $\beta = 0.95$)⁴⁵. A sample of 21 elite female football players were recruited to participate. The participants had all played professionally in the Portuguese Premier League for at least two seasons, all of them played for their national teams (Portugal and Brazil), and trained regularly 5 ± 1 hr sessions per week.

Following the Participant Classification Framework ⁴⁶, the competitive level of our participants corresponded to Tier 4 – Elite/International Level. We collected anthropometric data before the protocol was initiated, such as height (Seca 213 portable stadiometer, Seca, Hamburg, Germany), body mass (BM), body mass index (BMI) and the body fat (Omron Body Composition Monitor BF511, Omron, Kyoto, Japan) (see Table 1).

Table 1. Profile of the elite female players (mean- *m*, standard deviation- *SD*, minimum- *minim*, maximum- *max*).

	<i>m</i>	<i>SD</i>	<i>min</i>	<i>max</i>
Age (years)	17.9	0.9	19	17
Years of Practice (y)	13	0.7	10	15
Height (cm)	164.57	4.99	158.00	176.00
BM (Kg)	58.50	5.58	50.00	72.70
BMI (Kg/m ²)	21.68	1.70	18.60	24.40
Body fat (%)	27.14	4.82	16.40	33.70

All participants were informed by oral and written communication about the experimental procedures. The study was approved by the Ethics Committee of the lead university (protocol number M25A21) and all procedures were conducted in accordance with the Declaration of Helsinki.

3.3.2 Study Measures

3.3.2.1 Ambient temperature

To control the ambient temperature, we used a Cubicle Tent (At-Home Cubicle Altitude Tent Standard 120 cm height x 96 cm x 72 cm, Hypoxico Altitude Training Systems, New York, USA), and two heaters to raise the ambient temperature (Heater 1500W, Hera Equation, Madrid, Spain). The temperature and humidity inside the tent were measured through the thermometer (C.A 895 hygrometry and environment, Chauvin Arnoux, Normandy, France; Accuracy: $\pm 0.1\%$ reading $+1^\circ\text{C}$) and a fan (VEN-SS-21245W, Sogo, Osaka, Japan).

3.3.2.2 Heart Rate

The exercise workloads were recorded using a heart rate (HR) strap device, recorded in 5-sec interval short-range telemetry (SRM DUAL ANT+, Bluetooth Smart running heart rate monitor, Schoberer Rad Meßtechnik, Jülich, Germany). To stipulate the HR_{max} of each player, the calculation of 220 minus the player's age was used ^{47, 48}.

3.3.3 Countermovement-jump

To evaluate the maximum height of the players (centimeters - cm), the strength (newtons - N), the power (watts - W) and the speed (meters per second – m/s) of the players' jump, the CMJ was performed, using the Optojump (Optojump Photocell System, Microgate, New York, USA) ⁴⁹. The Optojump is an optical measuring system, which can be used for vertical jump height measurement. It consists of two bars, a transmit and a receive bar, each measuring 39.4 x 1.2 x 1.6 inches and containing between 33 and 100 LEDs ⁴⁹. The system detects any interruption in communication between the bars and calculates their duration. This process makes it possible to measure flight and contact times during the performance of a series of jumps with an accuracy of 1/1000 of a second ⁴⁹. Each player performed three successful CMJs from a standing position, with the hands on the hips. Rest periods of half a minute between the jumps were provided. Additionally, players were instructed to jump as high as possible with both feet ⁴⁹.

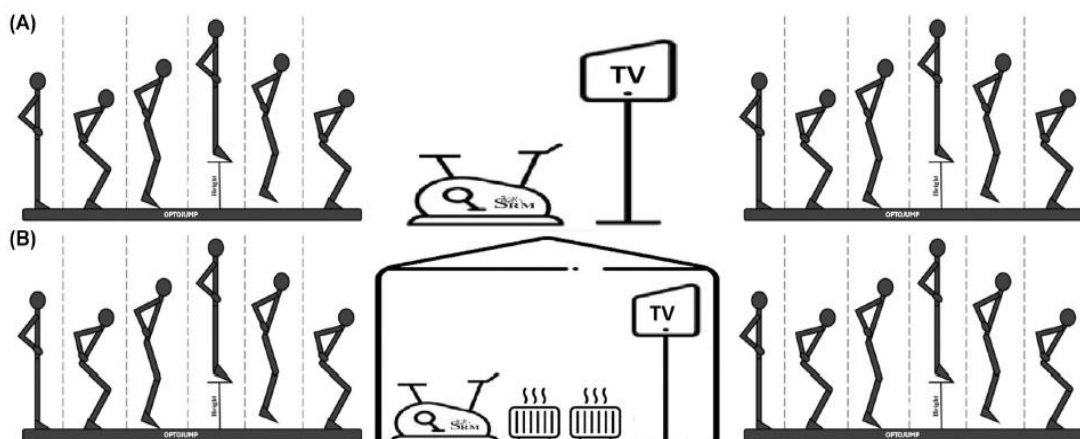
3.3.4 Anticipation

A total of 40 randomized and counterbalanced offensive scenarios (i.e., mild temperature: 10 clips were presented pre- and 10 clips post-protocol; hot temperature: 10 clips were viewed pre- and 10 clips post-protocol) from a third-person perspective ³ were projected onto a screen (50" LG UHD 4K Smart TV - UR80, LG Electronics, Busan, South Korea). The footage was filmed from 15m and 5m behind the goal using a 16 by 9 video camera (DSR 570 DVCAM, Sony, Tokyo, Japan) to ensure a full view of the field and preserve crucial wide positional information. The duration of each clip was approximately 5 s, with an inter-trial period of 5 s. A small circle appeared on screen to indicate the initial position of the ball just before the start of each clip. The clips were all occluded 120 ms before the player in possession of the ball was about to make a pass (i.e., action when the player attempted to play the ball to a teammate), or shoot at goal (i.e., when the player makes an attempt to score a goal), or retain possession (i.e., when the player has ball possession and attempts to move with the ball). To obtain the response accuracy (RA) scores calculated based on participant responses after viewing each clip (in percentages). An accurate response was recorded if the participant correctly anticipated the decision of the player in possession of the ball compared with what truly happened in the match situation.

3.3.5 Study design

Before commencing the task, the test procedure was explained, the HR device was adjusted and participants were instructed to perform a 2 min warm-up on the ergometer cycle at 75 RPM⁵⁰. After and before the intermittent exercise protocol³³, participants were instructed to perform the CMJ test and, while seated on the cycle ergometer, were asked to anticipate 10 clips pre- and 10 clips post-protocol, in each temperature condition. The height and saddle distance of the computer-controlled stationary cycle ergometer (SRM Ergometer, Schoberer Rad Meßtechnik, Jülich, Germany) was standardized for each participant. Based on the players' BM, the high-intensity loads (4 W/kg) were calculated and, together with the low-intensity loads (75 W), imported into the computer. An individualized cycle protocol relative to players' BM was used to standardize the intensity between participants. After a warm-up, each player performed the protocol for a total duration of 8 min, divided into 8 blocks of intermittent exercise (each block had 1 min). In each block, players alternated high-intensity exercise at 4 W/kg for 40 seconds and low-intensity exercise at 75 W for 20 seconds. During the first 15 seconds, both in periods of high intensity (4 W/kg) and periods of low intensity (75 W), the workload was always changed continuously, to avoid abrupt transitions between exchanges of workload across the protocol. At the end of the 8 minutes of protocol, a cooling of 1 min at 75 W was performed. Throughout the protocol, the players were instructed to maintain the cycling frequency between 70 and 80 rotations per minute (RPM).

The players were evaluated at three different moments, with a one-week interval between each test session. The participants performed the CMJ, the anticipation test (10 clips), the intermittent exercise protocol, the anticipation test (10 clips), and, lastly, the CMJ in the same order across all three test sessions. The initial test session was to familiarize the



participants with the experimental procedures, while in the second session participants completed the entire protocol design exposed under a mild environment temperature (20° C and 30% rh), and, finally, the participants completed the protocol design with the influence of hot environment temperature (38°C and 80% rh) ⁵¹ (Figure 1a and 1b).

Figure 1a - The experimental task used in the mild environment temperature. **Figure 1b** - The experimental task employed in the hot environment temperature.

3.3.6 Statistical Analysis

Before conducting the statistical analysis, data preprocessing steps were applied. Our analysis involved the use of Linear Mixed Models (LMM) after verifying the necessary assumptions, which include assessing the normality of residuals and ensuring homoscedasticity of variances ⁵². The assumptions of residuals normality and variances homoscedasticity were assessed thoroughly to ensure the validity and reliability of the LMM results. To examine the assumption of residuals normality, we conducted several diagnostic tests, namely the distribution of residuals using histograms, Q-Q plots, and probability plots. Variances homoscedasticity was assessed by observing standardized residuals vs fitted values plots in search for a random pattern. The Breusch-Pagan test was used to determine whether the variances of residuals were constant across different levels of the independent variables. All tests were non-significant. We employed a 2 x 2 design to assess the outcomes before and after the protocol in both non-heated and heated environments. Additionally, a one-way design was utilized to compare non-heated and heated environments for the outcomes assessed during the protocol. This design allowed us to evaluate the impact of the protocol under different environmental conditions. The LMM with unstructured covariance matrix approach was chosen for both analyses due to its suitability for handling repeated measures and accounting for within-subject correlations. LMM utilizes a maximum likelihood solution, which does not assume complete data ⁵².

The use of LMM allowed us to capture individual variability and assess the effects of multiple factors simultaneously, leading to a more robust and comprehensive analysis. To enhance the reliability of our analysis, we adopted a data-driven approach, employing the Restricted Maximum Likelihood (REML) estimation method, more appropriate for dealing with unbalanced data, providing unbiased estimates of fixed effects. All LMM models were adjusted for BM (Kg) to control for its potential influence on the outcomes measured. BM was treated as a covariate to account for its effects, thus enhancing the accuracy of our

analyses. We analysed the data using IBM SPSS Statistics, version 28.0 (IBM Corp, Armonk, NY) and the significance level was set at $p < 0.05$. Partial eta squared (η_p^2) values were provided as a measure of effect size for all main effects and interactions, considering that $\eta_p^2 = 0.01$ represents a small effect, $\eta_p^2 = 0.06$ represents a medium effect, and $\eta_p^2 = 0.14$ represents a large effect⁵³.

3.4 RESULTS

The average and peak HR data exhibited a linear increasing trend over the protocol (Figure 2a). Moreover, and using LMM, the HR values observed highlighted the remarkable consistency of the cardiovascular response of the female football players during the protocol.

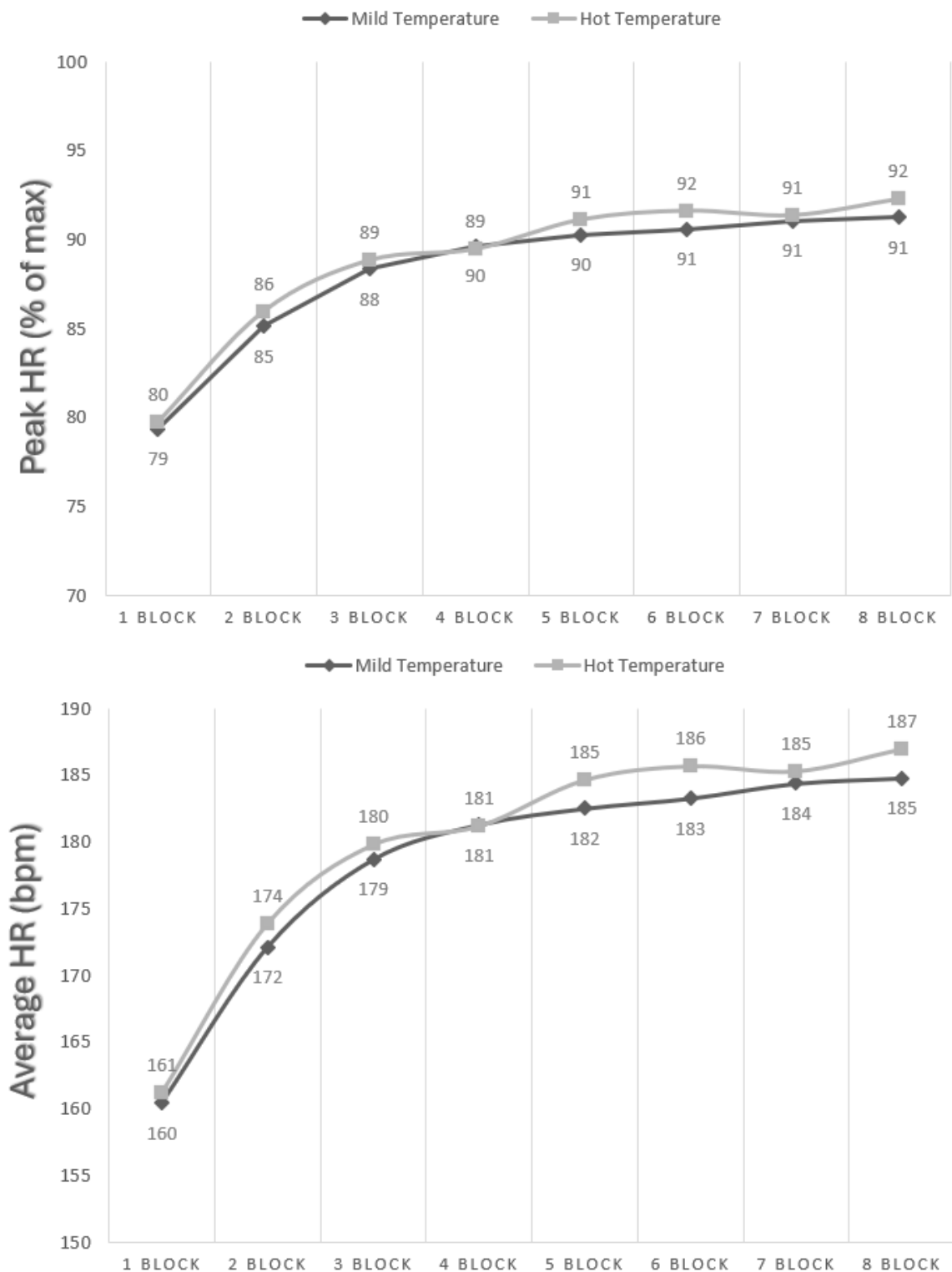


Figure 2a – The players' Heart Rate (HR) performance on the cycle ergometer during the intermittent exercise protocol ³³, under both conditions (mild environment temperature vs hot environment temperature).

The results regarding cycling frequency (RPM) revealed a decreasing performance in the hot when compared to the mild environment, particularly during the 5th block ($p<0.05$) (Figure 2b). Moreover, the power (W) generated all over the protocol was significantly higher in the 4th ($p=0.04$) block when participants were exposed to a mild environment temperature and significantly lower in the 8th block ($p=0.04$) during the hot environment condition. Lastly, we observed that cycling speed were significantly higher during the 5th ($p=0.03$) and 8th blocks ($p=0.02$) (Figure 2b) when the participants were exposed to the hot compared with the mild temperature environment. Additionally, of the 21 elite female players who participated under the mild environment temperature conditions there were 6 withdrawals (2 at 7th block, and 8 at 8th block) and when exposed to hot environment temperature there were 11 withdrawals (1 at 6th block, 8 at 7th block, and 2 at 8th block) before the end of the intermittent exercise protocol.

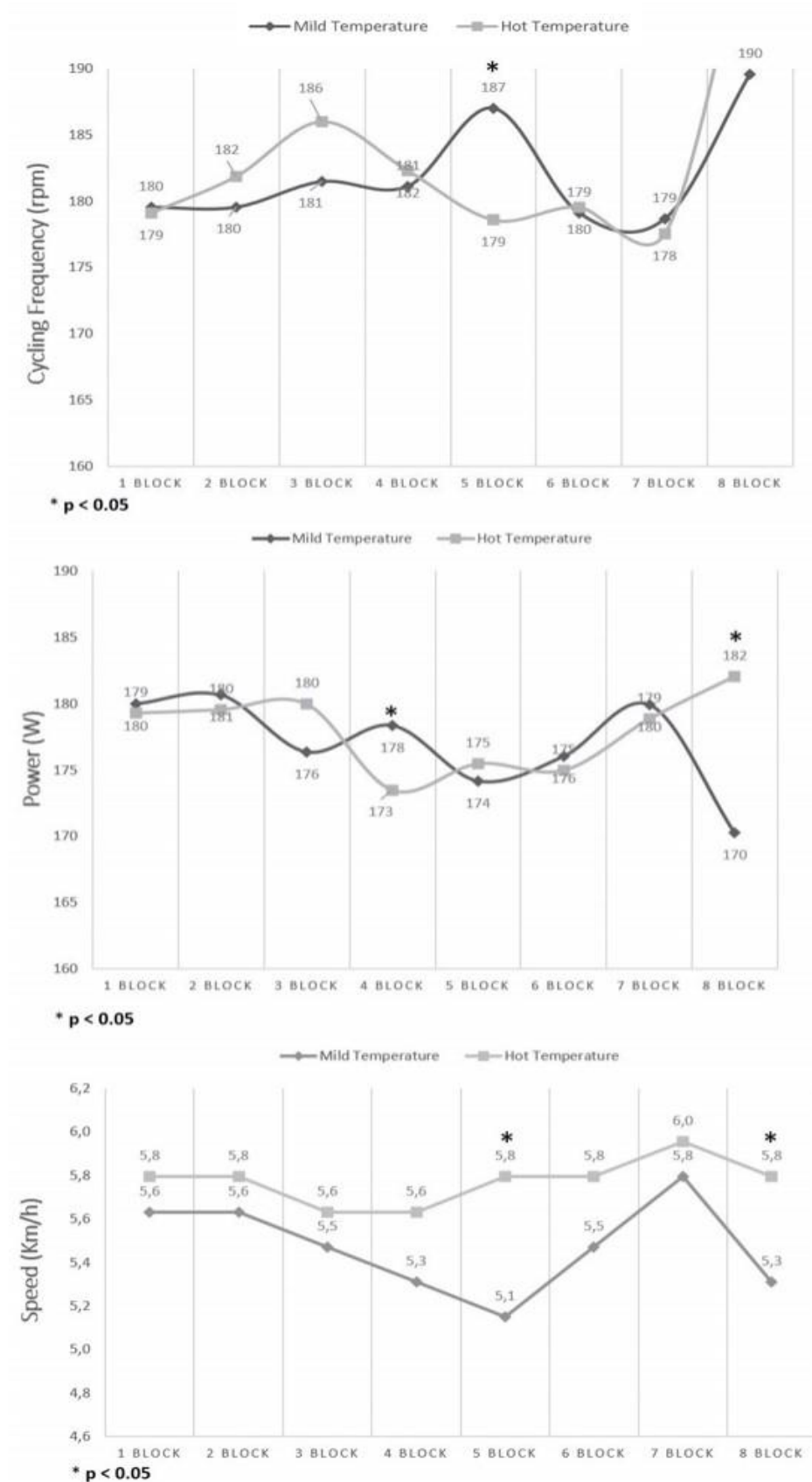


Figure 2b – The players' cycling (RPM), power (W), and speed (km/h) performance during the intermittent exercise protocol ³³ on both conditions (mild environment temperature vs hot environment temperature).

The CMJ performance results showed a loss of Strength (N) ($F_{(1,79)} = 10.39$, $p=0.002$; $\eta_p^2 = 0.12$) after performing the protocol, regardless of the environmental temperature, with an average decrease of 97.83 N (95% CI= 37.41; 158.24). No main effect was found for hot temperature environment on CMJ strength ($F_{(1,79)} = 0.00$, $p = 0.955$; $\eta_p^2 = 0.01$). Moreover, there were significant main effects for protocol on CMJ speed (m/s) ($F_{(1,79)} = 10.96$, $p = 0.001$; $\eta_p^2 = 0.12$), CMJ power ($F_{(1,79)} = 10.22$, $p = 0.002$; $\eta_p^2 = 0.11$), and CMJ Height_{max} ($F_{(1,79)} = 10.73$, $p=0.002$; $\eta_p^2 = 0.12$) (Table 2). There were no effect for hot temperature environment on CMJ Power ($F_{(1,79)} = 0.00$, $p = 0.958$; $\eta_p^2 = 0.00$), CMJ Height_{max} ($F_{(1,79)} = 0.00$, $p = 0.987$; $\eta_p^2 = 0.00$), CMJ Speed ($F_{(1,79)} = 0.08$, $p = 0.783$; $\eta_p^2 = 0.00$). There were no significant Protocol*Hot temperature environment interactions for CMJ Strength ($F_{(1,79)} = 0.08$, $p = 0.780$; $\eta_p^2 = 0.01$), CMJ power ($F_{(1,79)} = 0.08$, $p = 0.777$; $\eta_p^2 = 0.00$), CMJ Height_{max} ($F_{(1,79)} = 0.08$, $p = 0.780$; $\eta_p^2 = 0.00$) and CMJ speed ($F_{(1,79)} = 0.08$, $p = 0.783$; $\eta_p^2 = 0.00$).

There was significant main effect for protocol on RA% ($F_{(1,79)} = 44.69$, $p<0.001$; $\eta_p^2 = 0.36$), with a reduction in RA% of 18.26%, from 82.67 % to 64.41 % (Table 2). Also, there was significant main effect for hot temperature environment on RA% ($F_{(1,79)} = 4.77$, $p = 0.032$; $\eta_p^2 = 0.06$), where the RA% decreased 25.8% (Table 2). Additionally, the largest difference was found when comparing the RA% before the protocol in mild environment temperature (82.67%) and after the protocol in hot environment temperature exposure (53.44%). There was no significant Protocol*Hot temperature environment interaction on RA% ($F_{(1,79)} = 1.31$, $p = 0.257$; $\eta_p^2 = 0.02$). This finding suggests that the reduction of RA% was higher in heated than in mild ambient environments (Table 2).

Table 2. The results obtained of the Linear mixed model for comparisons before and after protocol considering both ambient environments.

	MILD AMBIENT TEMPERATURE		HOT AMBIENT TEMPERATURE		Protocol effect		Hot temperature effect		Protocol x Hot temperature effect	
	<i>Before protocol</i>	<i>After protocol</i>	<i>Before protocol</i>	<i>After protocol</i>	<i>F</i> (1,79)	<i>p</i>	<i>F</i> (1,79)	<i>p</i>	<i>F</i> (1,79)	<i>p</i>
Height _{max} (cm)	29,82 ± 0,68	27,38 ± 0,69	29,64 ± 0,68	27,58 ± 0,69	10.73	0.002	0.00	0.987	0.08	0.780
Strength (N)	1886,37 ± 30,36	1780,02 ± 30,37	1879,58 ± 30,36	1790,27 ± 30,37	10.39	0.002	0.00	0.955	0.08	0.780
Power (W)	22865,75 ± 619,46	20709,81 ± 619,70	22722,23 ± 619,45	20918,36 ± 619,74	10.22	0.002	0.00	0.958	0.08	0.777
Speed (m/s)	12,08 ± 0,14	12,04 ± 0,14	11,61 ± 0,14	11,57 ± 0,14	10.96	0.001	0.08	0.783	0.08	0.783
Response accuracy (%)	82,67 ± 3,30	64,41 ± 3,30	79,24 ± 3,30	53,44 ± 3,30	44.69	<0.001	4.77	0.032	1.31	0.257

3.5 DISCUSSION

We analysed the impact of a hot environmental temperature on physical and perceptual-cognitive performance in elite female football players while performing an intermittent exercise protocol. We predicted that performance on CMJ measures and our test of anticipation performance would be lower after the intermittent exercise protocol, regardless of the temperature exposure. We further hypothesised that hot environment temperature would negatively impact performance on the anticipation test in our sample of elite female football players.

The results of this study confirmed the formulated hypothesis, revealing that the intermittent exercise protocol had a significant adverse impact on all measures related to CMJ as well as the anticipation performance of female football players. Moreover, it was evident that hot temperature environment (38°C and 80% rh) had a negative influence on the players' ability to anticipate.

During the eight blocks of the intermittent protocol, players demonstrated a linear increase in average HR and peak HR throughout the test. From the 5th block onwards, players had already reached, on average, 90% of their peak HR. The average HR was higher across all blocks when the players performed the protocol under a hot when compared to a mild temperature. The same pattern was observed with the peak HR, which was higher when exposed to a hot temperature. Our findings support previous research, which showed that HR was higher during hot conditions, when compared to mild temperature exposure across all the cycling intermittent sprint protocol ². Additionally, the gradual increase of the players' HR across the intermittent exercise protocol suggests that female players were experiencing an increase in their physical exertion levels throughout the protocol, suggesting that the exercise intensity and cardiovascular demands increased progressively, ending with physical stress ⁵⁴.

Furthermore, the observed differences in average HR between hot and mild temperatures emphasized the influence of environment on cardiac response during exercise ⁵⁵. Hot temperature tends to increase thermal overload on the body, which can result in greater cardiovascular demand to help dissipate heat and maintain adequate body temperature ⁵⁶, leading to peripheral fatigue ⁵⁷. We can presume that all the participants experienced the physiological strain ^{58, 59} imposed by the cycling-based protocol used, since metabolic heat

production experienced during running activity tends to be higher⁶⁰. Moreover, excessive heat can impair efficient muscle contraction, leading to decreased strength, endurance, and coordination⁶¹. Donnan et al.² reported similar findings when male football players significantly reduced their workload during the second half of a cycling intermittent sprint protocol in heat conditions.

Moreover, when exposed to a hot environmental temperature, the players did not decrease their cycling cadence, expressed in RPM, resulting in a higher average speed, and generating more Watts at the end of the protocol. These results suggested that, even with the increase in thermal stress, the players were able to maintain or even improve their displacement on the cycle ergometer, demonstrating improved performance compared to the mild environment temperature.

The results for the CMJ test revealed that female players decreased their CMJ performance during both temperature conditions, albeit the physical performance was more affected by the intermittent exercise protocol than under a hot environment temperature. One of the main observations was the reduction in the Height_{max} of the jump, which indicates that the intermittent exercise protocol affected the ability of the players to generate vertical momentum and to increase vertical height. The decrease in the maximum jump height can be attributed to peripheral muscle fatigue caused by the intermittent effort performed⁶², resulting in a lower ability to produce the power needed to rise properly during the CMJ⁶³. Hence, both intermittent effort and hot environment temperature exposure reduced the ability to generate muscle strength and may affect the proper activation of motor units and muscle contractility, respectively.

Another important finding was the decrease in the jumping speed of the players after the performance of the intermittent protocol, exacerbated by the exposure to hot environment temperature conditions. The reduction in jumping speed suggests a decrement in movement efficiency and in the ability to produce the adequate amount of explosive force needed to achieve maximum speed⁶³. Therefore, this factor can be pointed out as the cause of the loss of speed in the CMJ performance of the players, with this negative impact increasing when the female players were exposed to hot environment temperature conditions.

The present study also provided a revealing insight into the impact of the intermittent protocol on the perceptual-cognitive performance of female football players. After executing the intermittent protocol, there was a clear decrease in the accuracy of the players' responses, indicating a negative influence on their cognitive function. These findings align with research

by Casanova et al.³ who showed that a fatigue-inducing protocol negatively influenced the accuracy of judgments in male football players. It appears that physiological workload has detrimental effects on the perceptual-cognitive processes underpinning anticipation¹³. Similarly, a drop in performance has been observed under high-intensity exercise, probably attributed to the brain's finite resources¹⁹.

However, the scenario became even more challenging when the same protocol design was implemented under hot environment temperature conditions. In this context, the accuracy of the players' responses was further impaired, highlighting the sensitivity of these players to environmental variations during the intermittent exercise protocol. To the best of our knowledge, no researchers have tested female football players using an intermittent exercise protocol while manipulating environmental conditions (air temperature and humidity). The results of the present study showed that exposure to heat led to a decrease in anticipation performance in elite female players. Our results mirror those reported by Donnan et al.² who examined the effects of hot (32°C, 50% rh) and mild environmental temperature (18°C, 50% rh) exposure on physical performance and soccer-specific decision-making in male football players after completing a 92-minute intermittent cycling sprint protocol. The results showed that the decision-making was impaired in the hot compared to the mild temperature condition. Similarly, Alder et al.⁶⁴ observed that response accuracy decreased in the separate physical and mental load conditions, when compared to baseline and worsened further in the combined load condition. The ability to anticipate is a fundamental skill for football players since it allows them to make quick and efficient judgements during matches⁶⁵, and it is negatively affected in hot temperature environments limiting the cognitive functions⁶⁶.

3.6 CONCLUSION

Our findings revealed that when elite female football players were subjected to the intermittent exercise protocol under two different conditions (hot and mild environment temperature) a reduction in performance was noted on a CMJ test as well as their ability to anticipate opponents' offensive actions. This latter finding suggests that while physical and cognitive performance was affected in both groups, heat exposure significantly exacerbated the decline in anticipation performance, highlighting the importance of specific training and conditioning strategies to deal with adverse environmental conditions.

3.7 PERSPECTIVE

While some previous reports have evaluated the effects of inducing fatigue on the physical abilities of female footballers ^{41, 42}, and the effect of fatigue on the mental abilities of the players ⁴³, the present study should encourage the scientific community to undertake further research on this topic. We hypothesized that female footballers would decline their efficiency to anticipate during matches in hot compared to mild temperature environments players. Moreover, our findings are essential to consider the environmental conditions during football training and competitions. Measures such as adequate hydration, gradual adaptation to the heat or cold and the implementation of cooling strategies can be adopted to minimize the negative impacts of heat on the physical performance of the players. In future, researchers should consider how performance is impacted by different climates and what role acclimatization players (male and female) in this response to heat stress. In addition, adjustments in training times, training loads, and exercise intensity may be necessary to ensure effective training and mimic the exposure of hot temperature environments.

ACKNOWLEDGMENTS

Thanks to all the staff of Jamor High Performance Center (Lisbon, Portugal), who collaborated to carry out this study.

CONFIRMATION OF ETHICAL COMPLIANCE

The study was granted ethical approval by the Lusófona University Research Ethics Committee (Protocol Number M25A21).

DECLARATION OF INTEREST STATEMENT

No potential conflict of interest was reported by the authors.

DATA AVAILABILITY STATEMENT

The data research is available in the paper.

FUNDING

This study had no funding.

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CAPÍTULO IV –

- DISCUSSÃO GERAL -

4.1 DISCUSSÃO GERAL

A presente tese de doutoramento teve como objetivo geral estudar o efeito temperatura ambiente no desempenho físico e antecipatório em futebolistas do sexo feminino durante a realização de um protocolo de exercício intermitente. Sabendo que para dar cumprimento ao objetivo geral, se definiram como objetivos específicos: (i) extrair e interpretar dados de estudos publicados que analisem o efeito da temperatura ambiente nas demandas físicas, fisiológicas e nos julgamentos antecipatórios de jogadores de futebol durante protocolos de indução de fadiga específicos para o futebol e, posteriormente, analisar, descrever e resumir as interpretações dos estudos elegíveis; (ii) conduzir um estudo piloto para avaliar o efeito de um protocolo de exercício intermitente (em ambiente laboratorial) sobre a taxa de produção de força em jogadoras de elite do futebol feminino em Portugal, por meio da análise do CMJ antes e após a realização do protocolo; (iii) analisar o efeito da temperatura ambiente sobre a capacidade física e antecipatória em futebolistas de elite femininas durante a realização de um protocolo de exercício intermitente.

De acordo com os resultados encontrados na presente tese de doutoramento, se constatou que: (i) não foi possível encontrar artigos relacionados sobre o efeito da temperatura ambiente elevada nas capacidades físicas, fisiológicas e antecipatória de jogadores ou jogadoras de futebol durante a realização de protocolos específicos de futebol que induzissem a fadiga, de acordo com os critérios P.I.C.O.S. definidos na revisão sistemática; (ii) o protocolo de exercício intermitente proposto por Lemmink e Visscher (2005) teve um efeito negativo no desempenho físico, em particular no CMJ, em futebolistas do sexo feminino; (iii) a temperatura ambiente elevada reduziu significativamente o desempenho do CMJ e da capacidade cognitiva (i.e., antecipação) após a realização de um protocolo de exercício intermitente, com maior influência negativa na capacidade antecipatória das futebolistas.

Primeiramente, no intuito de fornecer uma base científica para os Estudos II e III, foi realizado uma revisão sistemática, visando melhor entender quais eram as linhas de investigação a respeito da temática científica abordada.

Assim, na revisão sistemática foi possível verificar que existe uma escassez de evidências que investigam diretamente o efeito da temperatura ambiente no desempenho físico, fisiológico e cognitivo em futebolistas do sexo feminino. Apesar da busca extensiva

em várias bases de dados, a pesquisa inicial realizada apresentou um total de 1.289 resultados (Cochrane Library: 1; EBSCO: 530; PubMed: 69; Scopus: 513; e Web of Science: 176). Após a remoção dos estudos duplicados, restaram 652 resultados. A partir da triagem de títulos e resumos para critérios de elegibilidade resultou na exclusão de 637 resultados, em que 71 foram excluídos por não serem estudos empíricos publicados em periódicos revisados por pares. No entanto, não foram identificados estudos que atendessem aos critérios P.I.C.O.S. adotados nesta revisão sistemática, sublinhando, assim, a carência de investigações significativas neste domínio científico. Esta constatação ressalta a urgência de estudos adicionais para preencher essa lacuna de conhecimento e validar as suposições teóricas sobre o impacto da temperatura ambiente no desempenho esportivo, em especial nas futebolistas.

Aliás, nenhum estudo científico analisado atendeu aos critérios de inclusão definidos devido ao fato de nenhum ter avaliado pelo menos dois grupos de jogadores de futebol expostos a diferentes temperaturas (isto é, temperatura ambiente elevada vs temperatura ambiente amena) e, simultaneamente, realizassem um protocolo específico de futebol que induzisse a fadiga física e avaliasse a capacidade antecipatória.

Não obstante, poucos estudos foram encontrados em que se propuseram a avaliar o efeito do calor em futebolistas. Em particular, quatro estudos foram os mais próximos dos critérios P.I.C.O.S. adotados para a revisão sistemática proposta (Benjamin et al., 2021; Clarke et al., 2011; Coull et al., 2015; Edwards et al., 2007), mas como mencionado anteriormente, nenhum deles abordou todos os critérios adotados nesta revisão sistemática. Nesses quatro estudos detectamos que o efeito do calor no desempenho em futebolistas foi analisado sem a utilização de um grupo controle, expondo e comparando seu desempenho a diferentes temperaturas, o que levou a resultados heterogêneos e dissimilares.

Por exemplo, o estudo realizado por Clarke et al. (2011) teve como objetivo examinar o efeito da ingestão de carboidratos e do pré-resfriamento nas respostas fisiológicas de 12 jogadores que jogavam em nível universitário. Usando um exercício intermitente específico do futebol e avaliando o seu impacto no desempenho subsequente ao exercício de alta intensidade em condições de temperatura ambiente elevada. O estudo de Clarke et al. (2011) não mediu a magnitude da relação entre uma variável independente e uma variável dependente, por esta razão os resultados obtidos podem ser questionados, pois não fica claro se as alterações no desempenho físico e mental dos jogadores foram apenas provocadas pela exposição à temperatura ambiente elevada ou pelo próprio protocolo. Fato este colmatado na nossa investigação, onde foi realizada essa análise estatística, o que se mostrou crucial na

análise dos resultados.

Outro ponto crítico detectado em alguns dos estudos excluídos da revisão sistemática foi quanto ao tamanho da amostra, isto é, os sujeitos utilizados nos estudos experimentais consistiam em uma amostra de 8 (Coull et al., 2015) ou 12 jogadores de futebol (Benjamin et al., 2015; Clarke et al., 2011; Edwards et al., 2007). Consideramos que o tamanho das amostras, tendo em conta a análise do poder amostral (G*Power), pode ser inadequado para chegar a conclusões robustas capazes de orientar tanto a comunidade científica quanto a esportiva. Também, observamos que apenas o estudo conduzido por Coull et al. (2015) implementou um procedimento de familiarização do protocolo aos sujeitos testados, o que nos levantou algumas preocupações acerca da confiabilidade dos resultados obtidos. Além disso, em todos estes quatro estudos (Benjamin et al., 2021; Clarke et al., 2011; Coull et al., 2015; Edwards et al., 2007), as variáveis fisiológicas coletadas (e.g., nível de desidratação e temperatura corporal) em jogadores de futebol foram realizadas utilizando procedimentos diferentes, o que nos levou a observar resultados heterogêneos em todos eles.

Concomitantemente, na presente tese de doutoramento se definiu analisar o efeito de um protocolo de exercício intermitente na performance da força em futebolistas do sexo feminino da elite do futebol em Portugal. Os resultados encontrados revelaram uma redução significativa no desempenho do CMJ após a implementação do protocolo de exercício intermitente, demonstrando um impacto negativo na capacidade de produção da força em futebolistas do sexo feminino. Também, é importante salientar que o CMJ é um indicador sensível da capacidade neuromuscular e da habilidade de produção rápida de força (Hughes et al., 2022).

Os dados obtidos corroboram a evidência existente na literatura que aponta para o impacto do protocolo de exercício intermitente na redução da capacidade das futebolistas em gerar força muscular (Morcillo et al., 2015). Além disso, embora focado em futebolistas de elite do sexo feminino, a pesquisa realizada enquadra-se em estudos anteriores conduzidos em atletas masculinos, evidenciando uma perda similar na capacidade de gerar força após a implementação de protocolos de indução de fadiga (Morcillo et al., 2015).

A diminuição dessa habilidade após o protocolo de exercício intermitente sugere a manifestação do aparecimento de fadiga periférica, afetando a capacidade dos músculos em sustentar o desempenho esperado (Amann et al., 2007). Esta descoberta é consistente com estudos anteriores que indicam uma diminuição na produção máxima de força após períodos de fadiga (McFarland et al., 2016).

Aliás, e a partir dos resultados obtidos, se enfatiza a relevância da força muscular no desempenho físico das jogadoras de futebol, especialmente em cenários de jogo que envolvem disputas aéreas e movimentos explosivos. Além disso, a redução na capacidade de produção de força pode afetar, diretamente, a habilidade de realizar movimentos como cabeceios e intercepções, que são fundamentos essenciais para o sucesso do futebolista durante o jogo (Marqués-Jiménez et al., 2022).

Também, importa alertar que os resultados obtidos na presente tese de doutoramento podem colaborar com a literatura da especialidade, em que futuramente poderá ter implicações práticas, auxiliando na elaboração de programas de treinamento para futebolistas do sexo feminino e, subsequentemente, aplicando um conjunto de estratégias que visem minimizar a fadiga muscular e preservar a capacidade de gerar força para otimizar o desempenho e reduzir o risco de aparecimento de lesões durante a competição (Murtagh et al., 2023). Além disso, a implementação do protocolo de exercício intermitente utilizado em investigações adicionais que pretendam estudar o impacto físico, fisiológico e respetiva adaptação de estratégias de treinamento específicas para essa população desportiva em concreto (futebolistas femininas).

A originalidade da presente tese de doutoramento, também, deve ser reforçada pela metodologia de investigação em que analisa o efeito da temperatura ambiente nas capacidades físicas e antecipatórias em futebolistas do sexo feminino durante a realização de um protocolo de exercício intermitente, numa perspectiva holística. Para tal, implementou-se a recolha de indicadores físicos, como: a avaliação do salto em contramovimento, analisando as medidas da altura máxima (cm), da força exercida (N), da velocidade (m/s) e da potência (W) do salto em contramovimento, antes e depois da realização do protocolo de exercício intermitente, em dois tipos de condição de temperatura ambiente, a saber: temperatura ambiente amena (20° C e 30% UR) e temperatura ambiente elevada (38°C e 80% UR).

A análise do desempenho das futebolistas, também, foi monitorada sobre o cicloergómetro durante a realização do protocolo de exercício intermitente proposto por Lemmink e Visscher (2005), onde foi monitorada a frequência cardíaca (FC), as rotações por minuto (RPM) e a velocidade (Km/h) das participantes, em ambas as condições de temperatura ambiente.

Já, o desempenho cognitivo foi avaliado através da percentagem do grau de acerto nas respostas antecipatórias, para isso, um total de 40 cenários ofensivos (ou seja, 20 cliques em cada momento de avaliação) foram apresentados a partir de uma perspectiva de terceira

pessoa (cf., Casanova et al., 2013) as quais foram projetados em uma televisão. E, em ambas as condições de temperatura (i.e., temperatura ambiente amena vs temperatura ambiente elevada).

Ao analisarmos os valores da FC obtidos verificamos um aumento linear ao longo do protocolo, indicando um aumento progressivo na demanda cardiovascular das futebolistas. Notavelmente, o desempenho no cicloergômetro foi afetado pela exposição à temperatura ambiente elevada, refletido pela diminuição da frequência de pedalagem, especialmente no 5º Bloco ($p < 0,05$) onde apresentou uma mudança significativa. Por outro lado, a potência gerada ao longo do protocolo foi significativamente diferente no 4º ($p = 0,04$) e no 8º bloco ($p = 0,04$) entre a exposição à temperatura ambiente amena e à temperatura ambiente elevada. Por fim, observamos que a velocidade de pedalagem foi significativamente inferior durante o 5º ($p = 0,03$) e 8º blocos ($p = 0,02$) entre as duas condições de temperatura ambiente a que as futebolistas foram sujeitas.

Ao avaliar o desempenho no salto em contramovimento, os resultados encontrados indicaram uma redução significativa na produção de força potente, velocidade e altura máxima após a execução do protocolo de exercício intermitente. Aliás, foram observados declínios significativos de desempenho na altura máxima ($p < 0,001$), na força ($p < 0,05$), na potência ($p < 0,01$) e na velocidade do salto em contramovimento ($p < 0,002$). Sendo essa redução ainda mais evidente quando as futebolistas foram expostas à temperatura ambiente elevada. Essas nossas descobertas sugerem, claramente, que a temperatura ambiente elevada exerceu um impacto negativo na capacidade das futebolistas em gerar força muscular e realizar movimentos potentes, afetando diretamente o seu desempenho físico.

Após a realização do protocolo de exercício intermitente, também, se constatou que a capacidade antecipatória das futebolistas de elite se reduziu significativamente quando foram sujeitas ao exercício em condições de temperatura ambiente elevada do que em condições de temperatura ambiente amena ($p < 0,001$).

Além disso, a percentagem de acerto nas respostas antecipatória das futebolistas foi comprometida significativamente (redução) após a realização do protocolo do exercício intermitente. A exposição à temperatura ambiente elevada exacerbou mais essa redução na capacidade antecipatória das jogadoras, destacando a sensibilidade dessas futebolistas às variações ambientais durante o protocolo. Segundo Cardoso et al. (2021) uma tomada de decisão mais rápida implica na maior capacidade de empregar estratégias de busca visuais e de processar informações, possibilitando assim maior eficiência cognitiva. Portanto,

compreender o impacto adverso da exposição à temperatura ambiente elevada na capacidade de decisão e antecipação de uma jogadora de futebol torna-se crucial. A habilidade de tomar decisões rápidas e precisas, juntamente com a capacidade de antever jogadas, são elementos essenciais para o sucesso da jogadora durante uma partida de futebol (Farrow & Raab, 2007).

Também, e de acordo com Kunrath et al. (2020), a fadiga mental entre jogadores de futebol resulta em uma redução na percepção periférica, levando a priorizar ações em direção à meta adversária e afetando negativamente as decisões táticas. Esse estado de fadiga mental, quando combinado com a exposição ao calor, pode agravar ainda mais esses efeitos prejudiciais, resultando em erros mais frequentes e afetando não apenas o comportamento cognitivo e tático, mas, também, implicando em um aumento compensatório no desempenho físico, mostrando como a influência do calor pode intensificar as dificuldades enfrentadas pelos futebolistas em campo (Donnan et al., 2022).

Assim, importa salientar que embora o protocolo de exercício intermitente adotado tenha afetado o desempenho físico e cognitivo em futebolistas de elite do sexo feminino, a exposição ao calor pareceu exacerbar esses efeitos adversos, evidenciando a influência crítica do ambiente térmico na capacidade de desempenho das futebolistas.

Em síntese, os resultados deste estudo sugerem que tanto o protocolo de exercício intermitente como a exposição à temperatura ambiente elevada afetaram negativamente as capacidades físicas e antecipatórias em futebolistas do sexo feminino. Além disso, os resultados encontrados evidenciaram que a temperatura ambiente elevada teve um efeito acentuado na redução da capacidade antecipatória das futebolistas de elite. Portanto, estratégias específicas de treinamento e condicionamento podem ser necessárias para enfrentar condições ambientais adversas e otimizar o desempenho das futebolistas em situações reais de jogo.

Não obstante, importa ressaltar algumas limitações investigacionais, tais como: a ausência de medidas de temperatura interna durante o protocolo e a execução de um protocolo de exercício em uma esteira rolante, o que de certa forma não reproduziu o padrão motor (corrida) das futebolistas.

Os três estudos realizados que constam na presente tese de doutoramento destacam-se pelo seu pioneirismo ao explorar e analisar o impacto da temperatura ambiente no desempenho físico e cognitivo em futebolistas do sexo feminino durante a realização de um protocolo de exercício intermitente. Em particular, os Estudos II e III assumem um papel importante ao preencher uma lacuna substancial na pesquisa científica (comprovada pelo

Estudo I), mostrando uma defasagem dentro da modalidade do futebol praticado por futebolistas do sexo feminino em comparação com futebolistas do sexo masculino.

CAPÍTULO V

- CONCLUSÃO -

5.1 CONCLUSÃO

A partir dos resultados obtidos dos diferentes estudos da presente tese de doutoramento, se destaca as seguintes conclusões:

- Na literatura científica não se observou estudos que analise o efeito que a exposição à temperatura ambiente elevada exerce nas capacidades físicas e antecipatórias em futebolistas, do sexo masculino ou feminino, durante a realização protocolos de indução de fadiga específicos para o futebol.

- As futebolistas de elite quando submetidas a um protocolo de exercício intermitente apresentaram uma redução significativa da sua capacidade física, medida por parâmetros como: altura, força, potência e velocidade do salto em contramovimento.

- As futebolistas submetidas ao protocolo de exercício intermitente, sob duas condições diferentes (temperatura ambiente amena e temperatura ambiente elevada), apresentaram menor desempenho no salto em contramovimento e na capacidade antecipatória. No entanto, a descoberta mais notável foi que a exposição à temperatura ambiente elevada teve um impacto negativo marcante na capacidade de antecipação das futebolistas de elite. Esta descoberta sugere que, embora os desempenhos físico e cognitivo tenham sido afetados em ambas as condições de temperatura, a exposição à temperatura ambiente elevada exacerbou significativamente o declínio no desempenho antecipatório das participantes.

Como possíveis recomendações futuras, devido a lacuna existente na pesquisa relacionada ao impacto ambiental específico nas futebolistas do sexo feminino, sugere-se a prioridade de aprofundar os estudos nesse campo, dada a sua relevância. Assim, a comunidade científica deve desenvolver estudos que abordem os efeitos que a exposição à temperatura ambiente elevada exerce nas capacidades físicas e cognitivas em futebolistas durante a realização de protocolos laboratoriais que simulem as exigências do jogo de futebol (tanto em tempo similar ao de uma partida como no seu padrão motor), para que seja possível fornecer ferramentas que ajudem a comunidade científica e técnica a identificar e superar possíveis causas subjacentes à perda de desempenho em futebolistas (de ambos os sexos), otimizando a sua capacidade de desempenho de jogo.

Por último, é essencial considerar as condições ambientais durante os treinos e competições de futebol. Medidas como hidratação adequada, adaptação gradual ao calor e implementação de estratégias de resfriamento podem ser adotadas para minimizar os impactos

negativos do calor no desempenho físico em futebolistas. Além disso, podem ser necessários ajustes nas cargas de treino e na intensidade do exercício para garantir um treino seguro e eficaz, especialmente em ambientes com temperatura ambiente elevada.

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ANEXOS

Supplementary Table S1. PRISMA Checklist.

Section and Topic	Item #	Checklist item	Location where item is reported
TITLE			
Title	1	Identify the report as a systematic review.	Page 1
ABSTRACT			
Abstract	2	See the PRISMA 2020 for Abstracts checklist.	Page 1
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of existing knowledge.	Pages 1-2
Objectives	4	Provide an explicit statement of the objective(s) or question(s) the review addresses.	Pages 3
METHODS			
Eligibility criteria	5	Specify the inclusion and exclusion criteria for the review and how studies were grouped for the syntheses.	Page 3-4
Information sources	6	Specify all databases, registers, websites, organisations, reference lists and other sources searched or consulted to identify studies. Specify the date when each source was last searched or consulted.	Page 4
Search strategy	7	Present the full search strategies for all databases, registers and websites, including any filters and limits used.	Pages 4-5
Selection process	8	Specify the methods used to decide whether a study met the inclusion criteria of the review, including how many reviewers screened each record and each report retrieved, whether they worked independently, and if applicable, details of automation tools used in the process.	Page 5
Data collection process	9	Specify the methods used to collect data from reports, including how many reviewers collected data from each report, whether they worked independently, any processes for obtaining or confirming data from study investigators, and if applicable, details of automation tools used in the process.	Page 5
Data items	10a	List and define all outcomes for which data were sought. Specify whether all results that were compatible with each outcome domain in each study were sought (e.g. for all measures, time points, analyses), and if not, the methods used to decide which results to collect.	Page 5
	10b	List and define all other variables for which data were sought (e.g. participant and intervention characteristics, funding sources). Describe any assumptions made about any missing or unclear information.	Page 6
Study risk of bias assessment	11	Specify the methods used to assess risk of bias in the included studies, including details of the tool(s) used, how many reviewers assessed each study and whether they worked independently, and if applicable, details of automation tools used in the process.	Page 6
Effect measures	12	Specify for each outcome the effect measure(s) (e.g. risk ratio, mean difference) used in the synthesis or presentation of results.	Page 6

Section and Topic	Item #	Checklist item	Location where item is reported
Synthesis methods	13a	Describe the processes used to decide which studies were eligible for each synthesis (e.g. tabulating the study intervention characteristics and comparing against the planned groups for each synthesis (item #5)).	Page 6
	13b	Describe any methods required to prepare the data for presentation or synthesis, such as handling of missing summary statistics, or data conversions.	Page 6
	13c	Describe any methods used to tabulate or visually display results of individual studies and syntheses.	Page 6
	13d	Describe any methods used to synthesize results and provide a rationale for the choice(s). If meta-analysis was performed, describe the model(s), method(s) to identify the presence and extent of statistical heterogeneity, and software package(s) used.	Page 6
	13e	Describe any methods used to explore possible causes of heterogeneity among study results (e.g. subgroup analysis, meta-regression).	Page 6
	13f	Describe any sensitivity analyses conducted to assess robustness of the synthesized results.	Page 6
Reporting bias assessment	14	Describe any methods used to assess risk of bias due to missing results in a synthesis (arising from reporting biases).	Page 6
Certainty assessment	15	Describe any methods used to assess certainty (or confidence) in the body of evidence for an outcome.	Page 6
RESULTS			
Study selection	16a	Describe the results of the search and selection process, from the number of records identified in the search to the number of studies included in the review, ideally using a flow diagram.	Page 6
	16b	Cite studies that might appear to meet the inclusion criteria, but which were excluded, and explain why they were excluded.	Page 6
Study characteristics	17	Cite each included study and present its characteristics.	Page 7
Risk of bias in studies	18	Present assessments of risk of bias for each included study.	Not applicable
Results of individual studies	19	For all outcomes, present, for each study: (a) summary statistics for each group (where appropriate) and (b) an effect estimates and its precision (e.g. confidence/credible interval), ideally using structured tables or plots.	Not applicable
Results of syntheses	20a	For each synthesis, briefly summarise the characteristics and risk of bias among contributing studies.	Not applicable
	20b	Present results of all statistical syntheses conducted. If meta-analysis was done, present for each the summary estimate and its precision (e.g. confidence/credible interval) and measures of statistical heterogeneity. If comparing groups, describe the direction of the effect.	Not applicable
	20c	Present results of all investigations of possible causes of heterogeneity among study results.	Not applicable
	20d	Present results of all sensitivity analyses conducted to assess the robustness of the synthesized results.	Not applicable

Section and Topic	Item #	Checklist item	Location where item is reported
Reporting biases	21	Present assessments of risk of bias due to missing results (arising from reporting biases) for each synthesis assessed.	Not applicable
Certainty of evidence	22	Present assessments of certainty (or confidence) in the body of evidence for each outcome assessed.	Not applicable:
DISCUSSION			
Discussion	23a	Provide a general interpretation of the results in the context of other evidence.	Page 7
	23b	Discuss any limitations of the evidence included in the review.	Page 8
	23c	Discuss any limitations of the review processes used.	Page 8
	23d	Discuss implications of the results for practice, policy, and future research.	Page 9
OTHER INFORMATION			
Registration and protocol	24a	Provide registration information for the review, including register name and registration number, or state that the review was not registered.	Page 10
	24b	Indicate where the review protocol can be accessed, or state that a protocol was not prepared.	Page 10
	24c	Describe and explain any amendments to information provided at registration or in the protocol.	Pages 10
Support	25	Describe sources of financial or non-financial support for the review, and the role of the funders or sponsors in the review.	Page 10
Competing interests	26	Declare any competing interests of review authors.	Page 11

Section and Topic	Item #	Checklist item	Location where item is reported
Availability of data, code and other materials	27	Report which of the following are publicly available and where they can be found template data collection forms; data extracted from included studies; data used for all analyses; analytic code; any other materials used in the review.	Pages 4, 5 and 10

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