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SA01

Human Cardiovascular Control in Hyperthermia – From Basic Mechanisms to Therapeutic Applications

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The beneficial effects of heat therapy in humans have been known for millennia. Passive heat therapy (evoked though exposure to hot water baths, hot sand immersion, sauna or use of specialised heating garments) induces a myriad of physiological responses. These include large increases in cardiac output and selective increases in skin, muscle, fat and bone blood perfusion in the extremities, head and torso, but the opposite response in the cerebral and visceral circulations. Aerobic metabolism rises in conditions of whole-body hyperthermia; yet the magnitude of the metabolic response is small, demonstrating a predominant role of thermal stimuli and thus thermosensitive mechanisms in the hyperthermia-mediated circulatory and thermoregulatory responses. When heat therapy is repeated, significant structural and functional adaptations occur. Long-tem thermotherapy is known to (i) increase resting blood flow and ankle-brachial pressure index, (ii) improve vascular endothelial function, cardiac function, insulin sensitivity, blood glucose homeostasis and arterial blood pressure, (iii) decrease pain scores, (iv) improve walking distance, and (v) provide symptomatic and functional benefit to a variety of patient populations. In this talk, I will discuss the acute physiological responses and chronic adaptations to heat therapy, with particular emphasis on the thermal mechanisms contributing to the control of circulation and how recent advances in knowledge and understanding afford new therapeutical applications to improve health and quality of life in individuals with low functional capacity.

SA02

Respiratory responses to environmental exposure to cold or hot air

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Excess mortality and morbidity from respiratory illnesses is commonly reported during episodes of unusually low and high temperatures. Reasons behind increased risk of adverse respiratory events during environmental cold and heat exposure are however poorly understood. The aims of this presentation are to i) highlight the main effects of cold and hot air exposure on airway function and pulmonary ventilation, and ii) discuss potential functional and clinical consequences of such effects (particularly in vulnerable groups, such as the very young, the very old and those living with a chronic lung condition).

One of the primary roles of the lungs is to condition inhaled air to 37°C and 100% humidity before it reaches the alveoli. When cold air is inhaled, excess heat and water loss within the airways may modify properties of the airway surface lining fluid, rendering it hyper-osmolar. In those individuals with inflamed airways (such as patients with asthma), hyper-osmolarity of the airway surface lining fluid triggers an inflammatory cascade that ultimately leads to narrowing of the airways (bronchoconstriction). This effect is particularly apparent at times of high ventilatory demand (i.e., during physical activity and exercise). In healthy individuals, inflammatory-mediated bronchoconstriction is usually not present. However, reflex bronchoconstriction (via cooling of the facial skin and/or activation of muscarinic receptors within the airways) may occur during exposure to sub-freezing temperatures in both, healthy and clinical populations.

In the heat, conditioning of inhaled air is easily achieved, limiting the risk for osmotically-driven bronchoconstriction. A rise in temperature above normal body temperature (as might occur during heatwaves or prolonged exercise) can however cause reflex (C-fibre mediated) bronchoconstriction, particularly in those individuals suffering from allergic asthma. Further, during uncompensable heat stress, elevations of body core temperature of 1 to 2°C lead to hyperventilation (both at rest and during exercise). While hyperthermic-hyperventilation has been widely studied in young and athletic populations, far less is known about its occurrence and functional/clinical impact in older and patient populations.

As earth is warming and cold and hot waves become more frequent, severe and long lasting, more mechanistic work is required to help develop effective strategies to protect the most vulnerable against adverse respiratory events.

SA03

Passive heating and inflammation

Christof Leicht[1]

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Epidemiological data suggest that regular exposure to passive heat, using methods such as sauna bathing and hot water immersion, is associated with a reduction in cardiovascular disease (CVD) risk. Reductions in CVD risk are also observed in those who regularly exercise, raising the possibility of shared physiological mechanisms. Given the well-documented inflammatory component of CVD, the role of inflammation in mediating the cardioprotective effects of passive heating hence warrants further investigation.

A single bout of exercise can induce an acute inflammatory response, which has been proposed as a mechanism explaining the long-term reduction of chronic low-grade inflammation seen with regular exercise. A similar mechanism may underlie the benefits of passive heating. Supporting this, blunting the increase in body temperature during exercise also attenuates the acute inflammatory response. Others showed that exposing isolated tissue to heat, without muscle contraction, can induce an inflammatory response. Whole-body exposure to heat induces an acute inflammatory response of a magnitude similar to low- to moderate-intensity exercise, and reductions in resting inflammatory markers have been documented in chronic passive heating studies. These findings imply that temperature itself, independent of muscle contraction, can modulate inflammation.

Further insights come from spinal cord injury models, which highlight the role of the sympathetic nervous system in inflammation. Adrenaline can independently induce an inflammatory response, but even in high-level spinal cord injury, which results in a blunted adrenaline response, passive heat exposure still triggers an inflammatory response. This, again, suggests an independent temperature-related mechanism, potentially mediated by heat shock elements. These have been suggested to help regulate the production of a key inflammatory marker, interleukin (IL)-6. The IL-6 response is primarily affected by core and muscle temperature, and not by alterations in skin temperature. This is relevant for the wider uptake of heat therapy, as locally cooling the skin, particularly the face, enhances thermal comfort and perceptions, potentially influencing adherence to long-term heat therapy protocols. Given that the sustainability of heat therapy is crucial for its potential health benefits, optimising perceptions of heat exposure may play a critical role in increasing its uptake.

Despite promising preliminary findings, the majority of passive heating studies have been conducted in acute settings in young and relatively healthy populations. However, the long-term effects, and the effects in other demographic groups, remain sparsely investigated. Given that inactive populations (e.g., those affected by pain, frailty, disability) often exhibit an elevated inflammatory profile, they may particularly benefit from heat therapy. Another practical shortcoming of some existing studies is the use of protocols of long duration (up to 2 hours) or intense heat stress (up to core temperatures of 39.5°C), raising questions about the feasibility of any implementation in a real-world setting. To better understand the therapeutic potential and use of heat therapy as a non-exercise intervention for cardiovascular health, future research should therefore focus on developing tolerable, yet effective, protocols for those at higher risk for CVD.

SA04

Acute and chronic impact of heat exposure on muscle-tendon properties and interplay: from muscle to movement.

Adèle Mornas[1]

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Nowadays, athletes are increasingly exposed to high environmental temperatures. While many studies investigated the effects of heat stress on human physiology, the effects of acute or repeated heat exposure on muscle-tendon properties and function are not fully understood in vivo. Therefore, the purpose of this work is to describe the responses of the neuromuscular and musculotendinous system (i.e., voluntary and electrically-evoked maximal and explosive force production, force-velocity and force-length relationships and elastic properties) in vivo, using ultrafast ultrasound, under heat stress. The experimental part of this work is based on three studies, focused on gastrocnemius medialis muscle-tendon unit. The first study aimed to determine the effects of passive heat exposure on muscle-tendon unit properties. Our results showed an acceleration of rate of force development in the early phase, while soft tissue stiffness decreased. The second study investigated the acute effects of heat exposure on muscle-tendon interactions and fascicle dynamics in active participants (i.e., during running). We demonstrated that muscle-tendon unit properties and operating fascicle lengths during running were unaffected by environmental temperatures up to 40 min of running at 10 $km.h^{-1}$. The third study measured the impact of active heat acclimation on muscle-tendon unit properties. While the training protocol (i.e., repeated low-intensity cycling sessions) induced effective physiological adaptations, the properties of muscle-tendon unit assessed and the performance in vertical jump were unchanged. These findings offer the opportunity to improve our understanding of human motor skills responses to heat stress and to provide practical recommendations to coaches and athletes exposed to hot environments.

SA05

The pathophysiology of heat illness

Orlando Laitano[1]

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Heat illness results from the body's impaired ability to regulate core temperature under thermal and exertional stress, leading to a cascade of physiological dysfunctions. This presentation will examine the underlying mechanisms of heat illness, with a focus on cardiovascular strain, thermoregulatory disruption, and systemic inflammation. Special emphasis will be placed on sex differences, highlighting recent insights into female-specific responses to heat stress and exertional heat stroke. These distinctions have critical implications for prevention and treatment strategies, particularly in athletic and military populations.

SA06

Sex differences, ovarian hormones, and intestinal permeability

Tess Flood[1]

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The gastrointestinal model of heat stroke, states that during prolonged exercise in the heat, blood is diverted from the hepato-splanchnic tissue in the intestine towards the skeletal muscle and skin causing gut ischaemia. Ischaemia of the gut caused by the sudden reduction in blood flow leads to the breakdown of the gastrointestinal barrier. The physical structure is formed by the gut epithelium, which lines the luminal layer of the gut with a series of para-cellular tight junctions. The compromised gastrointestinal barrier increases permeability of the epithelial tight junctions which allow gram negative bacteria to translocate across the gut barrier into the portal circulation where it is transported to the liver. Lipopolysaccharide is located in the walls of the gram negative bacteria; these bacteria are usually contained within the intestinal lumen by the gastrointestinal barrier however, in conditions of augmented permeability the entry of these bacteria into the systemic circulation has been shown to induce an inflammatory response i.e., endotoxemia. Within research intestinal permeability is typically assessed using the urinary ratio of orally administered non digestible, non-metabolised probes, typically lactulose (paracellularly) and L-rhamnose (transcellularly). Research indicates that intestinal permeability can be influenced by endogenous oestrogen – a key ovarian hormone that fluctuates throughout the menstrual cycle. It is thought that oestrogen acts through oestrogen receptors found in the nucleus of the cell which potentiates the tight junction protein occludin which increases the adhesion of the tight junctions. Therefore, theory would suggest that intestinal permeability will fluctuate across the menstrual cycle with changes in oestrogen concentration. Oral contraceptives downregulate endogenous oestrogen production and instead provide an exogenous version (ethinyl-estradiol) which mimics the effects of oestrogen in the body. These reductions in endogenous oestrogen may increase intestinal permeability.

To conclude, this talk will summarise research examining the influence of sex differences including ovarian hormone fluctuations across the menstrual cycle and hormonal contraceptives have on intestinal permeability and implications for women in heat stress.

SA07

Effect of passive heat exposure on vascular function in adults with cardiovascular risk factors or established cardiovascular disease.

Amelie Debray[1], Hugo Gravel[2], Katia Oubouchou[3], Amine Dahhak[4], Steven A. Romero[5], Denis P. Blondin[6], Daniel Gagnon[7]

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Background: Regular heat exposure is gaining recognition as a potential lifestyle intervention to improve cardiovascular health. Observational data from Finnish and Japanese cohort studies show that frequent sauna use or hot water bathing is associated with a significantly lower risk of cardiovascular events and mortality. These associations remained robust after adjustment for confounders and included adults with cardiovascular risk factors, including type 2 diabetes. While these findings support a potential cardioprotective role for heat therapy, causal relationships have yet to be confirmed. The leading hypothesis is that regular heat exposure enhances vascular health, but this remains to be validated in clinical populations through well-controlled trials.

Objective: This work provides an overview of two studies testing the hypothesis that passive heat exposure improves markers of macrovascular and microvascular function, as well as blood pressure, in adults with either stable coronary artery disease (Study 1) or type 2 diabetes (Study 2).

Methods: In study 1, 41 adults (62 ± 6 years, 29.0 ± 4.3 kg/m^2, 33 men/8 women) with stable coronary artery disease were randomized to 8 weeks of Finnish sauna use (n=21, 4 sessions/week, 20-30 min/session) or control intervention (lifestyle maintenance, n=20). In study 2, 18 adults (66 ± 9 years, 28.2 ± 5.4 kg/m^2, 11men / 7women) living with type 2 diabetes were randomized to a 12-week home-based heat therapy (leg immersion in 42°C water, n=10) or sham (leg immersion in 36°C water, n=8) intervention (3-5/week, 45-60min/session). In both studies, peripheral endothelial function (brachial artery flow-mediated dilation, baFMD), microvascular reactivity (post-occlusive reactive hyperemia), and blood pressure, were measured before and after the intervention.

Results: In Study 1, no significant differences were observed between interventions for changes in baFMD (p for interaction = 0.82), systolic (p = 0.951), or diastolic (p = 0.292) blood pressure. However, changes in total (p = 0.031) and peak (p = 0.024) reactive hyperemia differed between interventions, driven by a nonsignificant decrease following sauna use and an increase in the control group. In Study 2, preliminary findings indicate that baFMD increased by 1.50% [95% CI: 0.39; 2.62] with heat therapy, compared to 0.16% [–1.08; 1.41] with the sham intervention. Changes in peak and total reactive hyperemia and in blood pressure did not differ between groups.

Conclusion: These results show that 8 weeks of Finnish sauna bathing did not improve markers of endothelial function, microvascular function or blood pressure in older adults with stable coronary artery disease (study 1). In contrast, preliminary results suggest that 12 weeks of home-based lower leg hot water immersion may improve endothelial function in adults with type 2 diabetes (study 2).

Significance: This project may identify a novel lifestyle intervention that improves markers of vascular health in adults living with type 2 diabetes.

SA08

Cold water therapy: a new hot topic

Heather Massey[1]

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Cold water immersion encompasses a range of practices, including wild swimming in natural environments, indoor cold showers, ice baths, and even applications in medical settings, such as during surgical procedures. For individuals engaging with online content, following social media influencers, or consuming print media, cold water immersion, whether through dipping, swimming, or full immersion, appears to be widely presented as a universal panacea or "cure-all." However, such claims are often vague or rely on flawed deductive reasoning, information removed from the context of the original research, or untested theoretical assertions, frequently without reference to rigorously controlled prospective trials, systematic reviews, or meta-analyses. Examples of these claims include 'boosted immunity, circulation, improved heart health, weight loss and increased circulation'.

While small-scale or pilot studies have explored some of the effects of cold water immersion more specifically, the scientific community has yet to produce adequately powered, well-designed, and rigorously controlled research to substantiate all claims. This calls for researchers to critically examine the often unverified and overly enthusiastic content freely disseminated, and to contribute robust findings to the scientific literature in order to either validate or refute these claims.

Although cold water immersion may provide certain benefits, the underlying mechanisms of action remain unclear, and the specific "dose of cold" required for positive outcomes has not been determined across all contexts of use. This lack of clarity creates a fertile ground for misunderstanding, misinterpretation, and the spread of misleading information. In this discussion, we will analyse existing evidence pointing to the potential benefits of cold water immersion, examine possible mechanisms of action, and consider the populations for whom these benefits may be most relevant.

SA09

Risks associated with hypothermic interventions

Clare Eglin[1]

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There is a growing interest in the use of thermal interventions to improve both physical and mental health. The premise being that a perturbation of the homeostatic system through thermal challenges will provoke some of the adaptations seen with exercise. This is very promising as it has the potential to impact groups who are unable or unwilling to exercise. However, like exercise, thermal interventions are not without risk and with widening participation the risks may not always outweigh the benefits. This discussion will consider the risks associated with cold interventions.

Cold water dipping or swimming is increasingly popular and will invoke a powerful sympathetic response on entry into the cold water. These initial responses, often called the cold shock response, are driven by a rapid fall in skin temperature and evoke an inspiratory gasp, uncontrollable hyperventilation, inspiratory shift, tachycardia and hypertension. The dyspnoea associated with the respiratory responses reduces breath hold time and can induce panic which may result in swim failure. Arrhythmias may also occur during this period particularly if there is intermittent submersion and breath-holding. In individuals with underlying cardiovascular issues, a population who may consider thermal interventions over exercise, this increased workload of the heart may result in a cardiovascular or cerebrovascular accident. These risks can be mitigated by careful health screening, reducing the rate of skin cooling (warmer water, slow entry, wetsuits) until the individual is habituated and by providing a safe swimming environment with easy egress points.

Nerve and muscle function are impaired with cooling and therefore as the duration of immersion increases swimming performance will be impaired, potentially to the point of swim failure. The decreased tactile sensation and impaired muscle function may also impair the ability to egress the water especially if balance and coordination are required (e.g. with wave action and rocks). Immersions longer than 30 minutes may cause hypothermia with the consequent decline in both physical and cognitive function. Even in the absence of hypothermia, cold water swimming can trigger transient global amnesia. Consideration should also be given to the continued fall in deep body temperature after getting out of the water and the consequent effects on driving performance if adequate and appropriate rewarming is not undertaken. Rewarming in a hot sauna could pose a further risk due to increased vascular strain in a hypovolemic individual.

Prolonged or repeated exposure to cold may aggravate Raynaud's Phenomenon symptoms and potentially cause non-freezing cold injury (NFCI) particularly in the extremities where intense vasoconstriction will occur. The dose of cold (duration and temperature) that causes NFCI is not known, though it is likely that the longer the hands and feet are cold (both during immersion and before complete rewarming) the greater the risk. All of the above risks will be exacerbated in ice baths as the rate of cooling and consequent magnitude of response will be greater.

Therefore, whilst thermal interventions are emerging as a potential exercise mimetic, like any medicine, they are not without side effects.

SA10

Heat stress in young and older adults: Cardiac adjustments and selecting the optimal cooling solution

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compared with other age groups, older individuals are at a greater risk for adverse cardiovascular events during heat waves. During the 1995 heat wave in Chicago, and the 2003 heat wave in France, the odds of mortality rose exponentially beyond 65 years, reaching a staggering 1 death per 100 people in those aged 90 and above. Although the links between extreme heat exposure and cardiovascular related deaths are strong in epidemiological studies, strong physiological links are less clear. More specifically, the mechanisms by which EHE increases the risk of conditions such as heart attack and cardiovascular decompensation are not fully resolved. In part I of this talk, the speaker will introduce classical studies and more recent experiments using modern imagine technologies (e.g., ultrasound, PET-CT). These studies will be used to illustrate the multiple pathways by which EHE stresses the cardiovascular system, and how this is augmented in older individuals and clinical populations.

In part II, the efficacy of different personal cooling solutions will be discussed. The speaker will focus on i) how different non-air conditioning solutions impact cardiac stress in young and older people, and ii) how these effects vary depending on the climate type (i.e., very hot dry vs hot-humid). Identifying cost effective solutions and how their efficacy depends on the prevailing climate type is critical for mitigating heat-related deaths in regions without air conditioning. The experiments in part I and II underscore the importance of high-quality physiological data in solving the emerging climate and health crisis.

SA11

Sex-specific considerations in thermal physiology

Jessica Mee[1]

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Males and females differ somewhat in their responses to heat stress, largely due to females having a reduced sweating capacity, specifically during periods of high heat loss requirements. Furthermore, hormonal fluctuations associated with the menstrual cycle modify responses to heat strain. For example, elevated progesterone concentrations during the luteal phase of the menstrual cycle increases resting body temperature, the onset threshold for sweating, and cutaneous vasodilation for heat dissipation. Furthermore, perimenopausal and menopausal females experience additional heat sensitives, with the occurrence of hot flushes and night sweats which elevate their thermal discomfort. Interestingly, females report feeling less prepared for a heat wave than males, experience more heat illness symptoms during a heat wave (Mee et al., manuscript in preparation), are more commonly diagnosed with heat illnesses, and there are more excess deaths reported in females during heat waves.

Despite compelling evidence of sex differences in responses to heat strain, detailed audits of research designed to reduce physiological strain and susceptibility to exertional heat illness reveal a substantial under-representation of females as study participants. Of that data that is available, females have been shown to differ in their heat adaptive responses, with females typically requiring additional thermal stimuli to achieve the same magnitude of adaptation compared to males. Furthermore, most studies evaluating acute heat mitigation strategies in female participants, have failed to establish a reduction in physiological strain, thus, the efficacy of acute heat mitigation strategies in females is limited. The lack of robust thermal research on female-specific considerations ultimately hinders consensus on female bespoke guidance. For example, heat mitigation guidelines, which aim to reduce physiological strain and susceptibility to exertional heat illness, are underpinned almost exclusively by research conducted in males, without consideration of issues associated with the biological and phenotypical sex differences, despite females likely being at greater risk.

Heat illnesses are largely avoidable with the implementation of appropriate, effective, accessible, and sustainable heat mitigation strategies combined with appropriate education. Very few individuals receive any heat mitigation guidance from their employer or access public guidance on how to stay safe during heat waves (Mee et al., manuscript in preparation). Despite this lack of education, females have reported a greater willingness (compared to males) to engage with educational resources to enable them to optimise their preparation for a heat wave and reduce the impact the extreme heat has on their health and wellbeing (Mee et al., manuscript in preparation). As such, furthering our understanding of how females respond to heat strain and heat mitigation strategies whilst enhancing the translation of research informed strategies to the lay public is of urgent priority.

C01

Circulatory, metabolic, thermoregulatory and inflammatory responses after passive exposure over 8 hours in four different temperature and airflow combinations: preliminary analysis

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Introduction

With global warming progressing, average outdoor temperatures during spring and summer are rising. These effects influence indoor environments, especially when limited mitigations are employed, like the use of fans, dehumidifiers, or air conditioners, or keeping windows closed due to environmental and personal preferences. Little has been established about the effect of high ambient temperature and low air quality on human physiological responses, as it pertains to indoor scenarios during summer. Previous research investigated isolated effects of high temperature or bad air quality, but not in combination. Moreover, the majority of heat-related thermoregulation research is conducted on active short-heat exposures rather than sedentary for long durations. To bridge these gaps, this study aimed to determine the effect of neutral vs. high ambient temperature and low vs. high airflow on the cardiovascular and thermoregulatory responses of humans in a controlled laboratory study. We hypothesize that high ambient temperature paired with low air quality (induced by low airflow) would impair physiological performance the most.

Methods

The study employed a cross-over single-blinded design. Participants were blinded to the airflow level, but due to its nature, the contrasting temperature was noticeable. 18 healthy women (n=11) and men (n=7) aged 19-39 years completed 4 non-consecutive test days. The four conditions of temperature and airflow combinations were: 23˚C LowTEMP-LowVent, 23˚C LowTEMP-HighVent, 35˚C HighTEMP-LowVent and 35˚C HighTEMP-HighVent. Individuals refrained from consuming any alcohol or engaging in high-intensity physical activity 24 hours before the measurements. Individuals were fasted for at least 12 hours before each test day.

Each test day consisted of 8 hours of exposure to one of the four conditions in a climate-controlled metabolic chamber. Participants followed the same schedule of activities (mainly sedentarily sitting) throughout each measurement day. A range of physiological and cardiovascular variables were assessed including heart rate (H10, Polar Electro, Finland), blood pressure (Mobil-o-graph, IEM, Germany), physical activity level (MOX, Maastricht Instruments, Netherlands), metabolic rates and calculated energy expenditure (Omnical Systems, Maastricht Instruments, Netherlands); amongst which mean skin temperature (14 ISO9886-defined locations (iButtons, Maxim, USA)) and core temperature (telemetric pill, Bodycap, France) are presented below. One-way repeated measures ANOVA were performed to compare mean skin temperatures and core temperatures in the four conditions.

As this study was just completed in March 2025, the analysis of the full set of outcome variables, including cardiovascular and metabolic outcomes, will be presented at the conference.

Results

Preliminary analysis showed that calculated mean skin temperatures and core temperatures were within normal ranges for healthy adults in all conditions. Mean skin temperatures and core temperatures were normally distributed (Table 1). The main effect of the conditions on mean skin and core temperatures was statistically significant and large respectively (F= 2.46e+05, p = 2e-16 and F = 17862, p <2e-16).

Conclusion

Mean skin temperatures and core temperatures were significantly different in all 4 of the high/low temperature and low/high airflow exposures over 8 hours. Further analysis is ongoing. It is anticipated that these thermophysiological responses translate to impacts on other assessed outcomes, and a complete analysis will be completed in due time.

Table 1. Core and skin temperature means and IQRs over 8 hours in 4 temperature and airflow combinations: Condition 1 - 23˚C LowTEMP-LowVent, Condition 2 - 23˚C LowTEMP-HighVent, Condition 3 - 35˚C HighTEMP-LowVent, Condition 4 - 35˚C HighTEMP-HighVent

Condition (N=18)	Core Temperature (˚C) - Mean (IQR)	Mean Skin Temperature (˚C) - Mean (IQR)	Proximal-Distal difference (˚C) - Mean (IQR)
Condition 1 - 23˚C LowTEMP-LowVent	37.12 (36.93 - 37.28)	32.07 (31.84 - 32.33)	-3.35 (-5.43 - -1.18)
Condition 2 - 23˚C LowTEMP-HighVent	37.09 (26.9 - 37.29)	32.07 (31.74 - 32.29)	-3.19 (-5.05 - -1.49)
Condition 3 - 35˚C HighTEMP-LowVent	37.37 (37.16 - 37.59)	35.54 (35.37 - 35.79)	0.045 (0.018 - 0.890)
Condition 4 - 35˚C HighTEMP-HighVent	37.36 (37.15 - 37.58)	35.53 (35.30 - 35.81)	0.158 (0.018 - 0.891)

C02

Acute hot water immersion does not reduce 24-hour blood pressure in young healthy adults

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Background

Passive heat exposure may be a therapeutic strategy to reduce blood pressure and improve cardiovascular health. Evidence within hypertensive populations indicates acute passive hot water immersion (HWI) causes hypotension that persists over 24 hours. It is currently unknown whether a 24-hour post-heat-exposure hypotensive effect exists in young, healthy individuals. This study aimed to determine the influence of HWI on blood pressure responses within the first hour and the following 24 hours after a single session of HWI.

Methods

To date, nine healthy males (26 ± 4 years; 85 ± 11 kg; 180 ± 5 cm) completed two experimental trials in a randomised order, separated by at least 48 hours. In the HWI trial, participants were immersed to the neck in 40.5°C water for 30 min, followed by an additional 30 min at waist level. In the time-of-day matched control (CON) trial participants rested seated in 27°C air. Thermoregulatory and cardiovascular measures were assessed before, during, and 1 hour following HWI and CON interventions. At the end of the 1-hour recovery period, an ambulatory blood pressure monitor was fitted to the participant for 24 hours. All statistical analysis was conducted in GraphPad Prism, with two-way analysis of variance conducted to assess differences in dependent variables during HWI and CON trials. Where significance was identified, using the critical P value of 0.05, post-hoc analysis was conducting using Bonferroni adjustment. Two-tailed, paired samples t-tests were conducted to assess 24-hour blood pressure data.

Results

Preliminary analyses demonstrate at 60 min of the interventions, core temperature and heart rate were higher during HWI than CON (CON, 36.9 ± 0.4°C; HWI, 38.8 ± 0.2°C, P <0.001; CON, 67 ± 6 bpm; HWI, 102 ± 11 bpm, P < 0.001) and mean arterial blood pressure (MAP) and diastolic blood pressure (DBP) was lower (MAP; CON, 84 ± 6 mmHg; HWI, 73 ± 6 mmHg, P =0.002; DBP; CON, 70 ± 7 mmHg; HWI, 55 ± 7 mmHg, P =<0.001). Systolic blood pressure (SBP) was lower during HWI compared to CON at 30 min of the intervention only (CON, 112 ± 5 mmHg; HWI, 105 ± 7 mmHg, P =0.049). Throughout the 1-hour recovery period, core temperature was higher after HWI than CON (trial effect; P <0.05). DBP was lower immediately post-HWI compared to CON (CON, 68 ± 9 mmHg; HWI, 57 ± 7 mmHg, P =0.013) returning to pre-immersion values within 10 minutes post-HWI. No differences were detected between HWI and CON for SBP and MAP during the 1-h recovery period (all P >0.058). 24-hour MAP, SBP and DBP responses were not different for daytime, nighttime or overall mean values between CON and HWI interventions when assessed using ambulatory blood pressure monitoring (all P >0.169).

Conclusion

Preliminary data from this study indicate that HWI reduces arterial blood pressure in young healthy adults. However, the hypotension did not persist beyond 10 minutes after ceasing HWI despite core temperature remaining elevated during the 1-hour recovery period.

C03

Heat stress and hypohydration occurs in standby divers exposed to warm environments

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Introduction: Standby divers must be fully dressed in the appropriate ensemble during military and commercial diving operations. These garments are often fully encapsulating and may result in heat stress when worn in warm environments. This heat stress may lead to hypohydration, which can result in reduced physical and cognitive capacity before the standby diver enters the water. Factors that contribute to heat stress include ambient temperature, the diving ensemble, and radiant heat load from direct sun exposure. Objective: We examined the physiologic responses to heat stress in subjects wearing a Viking HD drysuit during one hour of exposure to dry-bulb temperatures of 33, 36, 39, and 42°C. Methods: Protocols were completed on four different days, and conditions were randomly assigned and delivered in an environmental chamber without radiant heat. Euhydrated subjects donned a heavy rubber drysuit over a lightweight base layer. The drysuit was appropriate for contaminated water diving with integrated boots and neck dam. Subjects also wore chemical protective gloves. Heart rate (HR), core (Tc), and skin (Tsk) temperatures were monitored during the one-hour exposure. Nude body mass was recorded before and after. Two-way ANOVA was used to analyze the data, and significance was set to p £ 0.05. Results: Eight subjects (4 males) aged 27±5 y completed all study conditions. HR and Tc increased over time ($p<0.001$). Mean seated HR peaked at 138±17 bpm in the 42°C and at 114±13 bpm in the 39°C condition. Peak Tc was 37.0±0.16, 37.1±0.19, 37.4±0.27, and 37.9±0.48 °C in the 33°C, 36°C, 39°C, and 42°C conditions, respectively and differed between all conditions ($p<.001$) except 33°C and 36°C ($p=.60$). The temperature gradient from Tc to Tsk was eliminated after 30 min in the 42°C condition and after 40 min in the 39°C. The Tc to Tsk gradient was nearly eliminated in the 36°C at the end of the 60 min exposure. Sweat rates of 0.17±0.09, 0.33±0.18, 0.57±0.4, and 0.82±0.5 L/hr were observed in the 33°C, 36°C, 39°C, and 42°C conditions, respectively and corresponded with a -0.20±0.10, -0.40±0.19, -0.69±0.46, and -0.99±0.55 % change in body mass. Sweat rate in both 39°C and 42°C was higher than 33°C ($p<0.001$). Conclusions: Even in the absence of radiant heating, significant hypohydration and heat stress occurs in standby divers after 30 min of exposure to 42°C and after 40 min at 39°C. Awareness of the conditions and rotation of standby divers could increase mission safety in these warm environments. Rehydration based on projected sweat rates can also be considered. Simple cooling strategies, such as hand/forearm immersion, could be examined to further manage heat stress in standby divers. Ethical Considerations: This study was approved by the University at Buffalo Institutional Review Board.

C04

A hot environment reduces exogenous carbohydrate oxidation during prolonged running despite maintaining a state of euhydration.

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INTRODUCTION: Exogenous carbohydrate oxidation (i.e., from drinks) is reduced in hot conditions[1,2]. Increased thermal and cardiovascular strain and reduced gastrointestinal (GI) integrity[3] may impair glucose uptake, gastric emptying, and absorption. Dehydration resulting from heat exposure, can also contribute to these impairments by reducing blood volume and altering blood flow distribution. As previous studies in hot conditions have not controlled hydration status, it remains unclear whether increased exogenous carbohydrate oxidation was due to increased core temperature or dehydration. Therefore, this study investigated the effect of running in a hot compared to temperate environment on exogenous carbohydrate oxidation, whilst maintaining a state of euhydration.

METHODS: Ten trained runners (24 ± 6 y; 72.7 ± 8.3 kg; $\dot{V}O_2$peak: 63 ± 6 mL/kg/min) completed a preliminary session ($\dot{V}O_2$peak and sweat rate testing) and two experimental trials [100 minutes of steady state running at ~65% $\dot{V}O_2$peak in either a temperate (19°C; TEMP) or a hot environment (32°C; HOT)]. Water was provided every 20 min to replace ~90% of body mass losses (TEMP: 795 ± 213 mL; HOT: 1665 ± 437 mL). In each trial, participants consumed 60 g/h (bolus every 20 min) of a 35% dextrose solution enriched with [U-^{13}C] glucose (145 ± 2 δ‰ enrichment). Expired breath (analysed for ^{13}C:^{12}C), blood samples and subjective scales of GI comfort were collected at rest and every 20 min during exercise. Data were analysed using linear mixed models (significance at $P < 0.05$). Results presented as mean ± SD. Institutional ethical approval was granted (LEON 16408).

RESULTS: Average (40-100 min) and peak exogenous carbohydrate oxidation rates were 20% (HOT: 0.43 ± 0.09 vs. TEMP: 0.54 ± 0.12 g/min; P = 0.006) and 18% (HOT: 0.67 ± 0.10 vs. TEMP: 0.81 ± 0.11 g/min; P = 0.002) lower in HOT than in TEMP respectively. Total carbohydrate oxidation (HOT: 2.72 ± 0.40 g/min vs. TEMP: 2.57 ± 0.34; P = 0.111) was not different between trials resulting in a greater contribution from endogenous sources in HOT (2.28 ± 0.38 vs. 2.03 ± 0.33 g/min; P = 0.020). Gastrointestinal temperature (HOT: 39.2 ± 0.4°C; TEMP: 37.9 ± 0.3°C; P < 0.001) and heart rate (HOT: 166 ± 14 bpm; TEMP: 137 ± 16 bpm; P < 0.001) at the end of trials were greater in HOT. In both trials body mass loss remained in a state of euhydration (± 1% body mass loss[4]) but was greater in HOT (-0.47 ± 0.51% vs. -0.04 ± 0.33%; P = 0.004). No difference was reported for changes in plasma volume (HOT: -9.0 ± 6.8%; TEMP: -10.3 ± 4.4%; P = 0.621). No differences in GI symptoms, including stomach bloatedness, were observed between conditions (P > 0.05).

CONCLUSION: Even with adequate hydration (within ± 1% body mass loss), running in a hot environment reduces exogenous carbohydrate oxidation likely due to impaired muscle glucose uptake, decreased intestinal absorption and slower gastric emptying. This led to a compensatory increase in endogenous carbohydrate oxidation to maintain similar total oxidation rates.

C05

Passive thigh heating improves peak force production in younger adults and the rate of isokinetic force production in younger and older adults

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Muscular function, largely absolute strength, predicates regular human function and contributes to a higher quality of life by supporting independent bodily movements and locomotion. Older adults often suffer from a reduced capability to complete physical activity or daily tasks relative to young adults due to limitations in muscle function. Prior work in young adults has identified passive heating as a potential ergogenic aid to improve muscle function, however the efficacy of the intervention has not been comprehensively explored in older adults. The primary aim of this study was to quantify the effect of 90 min of passive thigh heating on peak torque, rate of force development and early force production during isokinetic contractions in younger vs. older adults. The secondary aim was to measure the retention/decay of the anticipated improvements in function in younger vs. older adults 30 min post cessation of heating.

Twenty-two healthy young (YOUNGER; 23 ± 3 y) and sixteen healthy older adults (OLDER; 68 ± 8 y) completed an experimental visit whereby one thigh was heated via a garment circulating 50°C water for 90 min with the contralateral limb remaining unheated. Four maximal knee extension contractions were performed at three isokinetic speeds (slow, 60°/s, moderate, 180°/s and fast, 300°/s) on both limbs at baseline and every 30 min thereafter for 120 min with the final timepoint used to quantify the retention/decay in response. Thigh (Vastus lateralis) muscle temperature was measured every 30 min with surface electromyography (EMG) implemented to monitor muscle activation.

Heating increased muscle temperature from baseline (31.7 ± 1.7°C) at 30 min (36.5 ± 1.5°C), 60 min (37.1 ± 1.4°C), 90 min (37.5 ± 0.7°C) and 120 min (35.5 ± 2.3°C), all $p < 0.05$. Heating increased peak torque during moderate (+11 ± 12 N.m) and fast (+7 ± 11 N.m) contractions in only YOUNGER participants relative to their control leg which remained unchanged ($p < 0.05$). Rate of force development was increased from baseline in HEAT by 229 ± 210 N.m.s-1($p < 0.05$) in YOUNGER and OLDER. Early force production increased from baseline in YOUNGER and OLDER during the slow contractions (+15 ± 15 N.m) in the heated leg ($p < 0.05$). Peak EMG was unchanged throughout the experiment across all contraction speeds.

Passive thigh heating increased muscle temperature by ~5°C during the protocol. Peak isokinetic force in younger adults improved during heating at moderate (+8%) and in younger and older during fast (+10%) contractile speeds. Rate of force development during slow isokinetic contractions increased from baseline by 29%. Early force production during slow isokinetic contractions increased from baseline in younger (+13%) and older adults (+28%) during passive heating. Whilst there are some observable differences in the peak torque responses of younger and older adults to passive heating, in aggregate, the intervention can be considered beneficial when implemented prior to exercise given improvements in the rate of force development and early force production irrespective of age.

C06

Neural control of body temperature during passive heat stress in males and females

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Introduction: Understanding how thermoregulatory responses differ between males and females could contribute to a better understanding of sex-related differences in heat vulnerability (1). Previous studies found that maximal sweating capacity is greater in males, in part due to greater cholinergic sensitivity of the eccrine sweat glands (2). It remains unknown if the neural control of body temperature differs between males and females during heat stress.

Objective & hypothesis: This study aims to determine the effect of biological sex on the neural control of body temperature during passive heat stress. We hypothesized that the onset threshold for increases in skin sympathetic nerve activity (SSNA), local sweat rate (LSR), and cutaneous vascular conductance (CVC) are equivalent between males and females.

Methods: Sixteen healthy males (21-39 yrs) and fourteen healthy females (21-36 yrs, low reproductive hormone phase) were exposed to passive heat stress with a water-perfused suit until core temperature increased by 1.2°C. SSNA was measured from the radial nerve by microneurography, on the same arm as measurements of forearm LSR and CVC. Core temperature was measured using a esophageal probe and mean skin temperature was calculated as a weighted mean of four sites. Mean body temperature (MBT) was calculated as a weighted summation of core (0.8) and mean skin (0.2) temperatures to determine the onset threshold for SSNA, LSR and CVC by segmented linear regression. Two one-sided t-tests (TOST) were performed to assess equivalence between groups, with equivalence boundaries set at ±0.18°C, determined based on prior research (3). Independent samples t-test were also performed to complement the interpretation of results. Data are presented as mean ± SD or mean differences (males – females) with [90% CI].

Results: The data are presented in Table 1. Baseline MBT was 36.08 ± 0.28°C for males and 36.37 ± 0.22°C for females. The change in MBT at the onset threshold for SSNA was 0.65 ± 0.17°C for males and 0.70 ± 0.24°C for females (mean difference: -0.06°C [-0.31, 0.20], p=0.65). For forearm LSR it was 0.87 ± 0.25°C for males and 0.81 ± 0.29°C for females (mean difference: 0.05°C [-0.15, 0.26], p=0.59). For forearm CVC it was 0.86 ± 0.26°C for males and 0.79 ± 0.29°C for females (mean difference: -0.07°C [-0.15, 0.29], p=0.52). TOSTs were not significant for any outcome (SSNA: t_1 = 2.01, p_1 = 0.97; t_2 = -1.06, p_2 = 0.84; LSR: t_1 = 1.31, p_1 = 0.90; t_2 = -2.41, p_2 = 0.99; CVC: t_1 = 1.06, p_1 = 0.85; t_2 = -2.38, p_2 = 0.99), indicating non-equivalence.

Conclusion: The change in MBT required to activate SSNA, forearm LSR, and forearm CVC is not statistically equivalent between females and males. However, the mean differences fell within equivalence boundaries and complementary difference testing does not show significant differences between groups, suggesting that the differences are unlikely to be physiologically meaningful. We conclude that the neural control of body temperature is unlikely to differ between males and females during passive heat stress.

Table 1. Body temperatures and onset thresholds in males and females.

	Males (n=16)	**Females (n=14)**	**p-value**
Baseline T_{core} (°C)	36.63 ± 0.23	37.01 ± 0.21	<0.01
Baseline T_{body} (°C)	36.08 ± 0.28	36.37 ± 0.22	<0.01
Baseline T_{skin} (°C)	33.98 ± 0.75	33.85 ± 0.57	0.57
SSNA onset (°C)	0.65 ± 0.17	0.70 ± 0.24	0.65
LSR onset (°C)	0.87 ± 0.25	0.81 ± 0.29	0.59
CVC onset (°C)	0.86 ± 0.26	0.79 ± 0.29	0.52

Values are presented as mean ± SD. Tcore, core temperature; Tbody, mean body temperature; SSNA, skin sympathetic nerve activity; LSR, local sweat rate; CVC, cutaneous vascular conductance. p-value is for an independent sample t-test.

C07

Thermal Strain Within A Mass Participation Running Event In Temperate Conditions: Comparison Of 10 Km, Half-Marathon And Marathon Responses

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INTRODUCTION:

Exertional heat illnesses (EHI) pose a significant health risk in endurance sports for both amateur and elite athletes. While climate change exacerbates this risk during sporting events, exercise intensity remains a critical contributing factor. Investigating heat strain experienced by individuals is essential to understanding sport-specific risks and evaluating existing heat stress policies. This study reports the thermal strain of a heterogeneous cohort of amateur runners participating in 10 km (10KM), half-marathon (HM), and marathon (M) events in Hong Kong in February 2025. The aim was to differentiate heat strain across event lengths and identify modifying individual characteristics, such as age, sex, and body composition. We hypothesized that the greatest heat strain would occur in the 10KM event.

METHODS:

Seventy-six runners (age 38 ± 13 [18–65] years) ingested two telemetry pills to monitor core body temperature (TCORE); pill 1 before bed, and pill 2 upon waking on race day. Participants were distributed across 10KM (n=20, age=34.2 ± 14.3, 8 females, 12 males, body fat percentage [BF%] 23.0 ± 11.3%), HM (n=27, age=38.3 ± 13.0, 12 females, 15 males, BF% 19.4 ± 6.9%), and M (n=29, age=40.5 ± 10.8, 8 females, 21 males, BF% 15.6 ± 6.5%). Runners wore a heart rate monitor with attached skin temperature sensor. Portable weather stations (Pulse 4G-LTE, XM Weather, Greece) were positioned every 5 km along race routes. Races began between 05:30–08:30 and concluded by 14:00.

RESULTS:

Mean ambient temperature during the competition was 13.3 ± 1.6°C (range 10.0–20.8°C), with relative humidity of 36.9 ± 4.3% (22–50%), Wet Bulb Globe Temperature (WBGT) of 9.7 ± 3.7°C (5.7–25.9°C), solar irradiance of 113 ± 197 W/m^2 (0–798 W/m^2), and wind speed of 0.7 ± 0.8 m/s (0–3.9 m/s). No cases of EHI were reported. Race durations (hours) were 01:00:49 ± 00:12:15 for 10KM (females: 01:00:00 ± 00:11:32; males: 01:01:14 ± 00:12:56), 01:58:44 ± 00:23:44 for HM (females: 02:02:26 ± 00:19:49; males: 01:56:09 ± 00:26:19), and 03:58:57 ± 00:36:52 for M (females: 04:05:53 ± 00:38:17; males: 03:56:25 ± 00:36:55). Starting TCORE was 37.5 ± 0.4°C (10KM), 37.7 ± 0.4°C (HM), and 37.4 ± 0.5°C (M), with finishing TCORE of 39.1 ± 0.6°C (+1.6 ± 0.7°C), 39.0 ± 0.6°C (+1.4 ± 0.6°C), and 38.5 ± 0.7°C (+1.1 ± 0.7°C), respectively. Peak finishing TCORE was 40.3°C (10KM), 40.2°C (HM), and 39.8°C (M). Changes in TCORE in females were 1.9 ± 0.6°C (10KM), 1.4 ± 0.6°C (HM), and 1.1 ± 0.7°C (M), compared to males: 1.4 ± 0.5°C (10KM), 1.3 ± 0.6°C (HM), and 1.1 ± 0.7°C (M).

CONCLUSION:

Significant environmental variability, particularly within solar irradiance and WBGT, was observed post-sunrise (circa 07:00) along the course. Single-point monitoring therefore fails to capture microclimate diversity. Greater changes in body temperature were generally observed in shorter events and in females. Further individual monitoring of varied athlete cohorts, combined with multi-location weather data, is necessary to enhance understanding of EHI risks in different sports for both amateur and elite athletes.

C08

Prospective cohort investigation of hydration status and exertional heat illness risk

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INTRODUCTION: The arduous nature of infantry training increases the risk of exertional heat illness (EHI), which in its severest form can be fatal. Widely considered EHI risk factors include low aerobic fitness, elevated wet bulb globe temperature (WBGT) and hypohydration (Roberts et al., 2023). Unfortunately, the evidence supporting hypohydration as an EHI risk factor lacks objective measures and comparator controls.

AIM: Prospectively examine the association between pre-exercise hydration status and EHI risk.

METHODS: Between June 2021 and July 2024, 805 males and 2 females enrolled on Royal Marine Recruit training provided written informed consent and completed data collection. Before a criterion loaded march, widely considered EHI risk factors were assessed e.g., low aerobic fitness, overweight status, previous EHI, heat acclimatisation status and physician diagnosed injury or illness within 28 days. The night before the loaded march (2100 h), participants swallowed a telemetry capsule for gastrointestinal temperature assessment. On the day of the loaded march, urine samples were provided upon awakening (~0530 h) and after breakfast prior to commencing exercise (~0700 h). The 6.4-mile loaded march took place under cool conditions (mean ± SD, WBGT 11.2 ± 3.6 °C) and was completed in 66 ± 2 minutes. Participants wore a long sleeve t-shirt, combat trousers and boots and carried a 14.5 kg load. Urine osmolality was measured using freezing-point depression and thresholds for hypohydration (>900 $mOsm.kg^{-1}$; Maughan et al., 2007) and euhydration (<500 $mOsm.kg^{-1}$; Dolci et al., 2022) adopted. EHI cases were classified as “mild” who reported exercise-induced headache, dizziness or nausea and “severe” who exhibited central nervous system (CNS) dysfunction (Roberts et al., 2023), peak gastrointestinal temperature typically ≥39.5 °C and, where available, evidence of end-organ damage. A total of 790 male participants were included in statistical analysis. N=2 females were removed due to insufficient representation in the sample population and N=15 males were removed who exhibited CNS dysfunction but for whom a peak gastrointestinal temperature was unavailable. Unadjusted and fully adjusted multiple logistic regression was used to examine the association between widely considered risk factors and EHI.

RESULTS: A total of N=118 participants were classified as mild EHI (15%) and N=40 as severe EHI (5%). Urine osmolality was similar upon awakening (710 ± 231 $mOsm.kg^{-1}$) and pre-exercise (687 ± 244 $mOsm.kg^{-1}$, t-test P>0.05) and the proportion of hypohydrated (23%) and euhydrated (22%) participants was similar at both time points (χ^2 P>0.05). Hypohydration was not significantly associated with EHI risk in regression models (awakening adjusted OR=0.78, 95% CI 0.44–1.38, P=0.39). However, adjusted regressions showed that EHI risk was increased by other widely considered risk factors, including low aerobic fitness (OR=2.68, 95% CI 1.56–4.61, P<0.01), previous EHI (OR=2.39, 95% CI 1.48–3.86, P<0.01) and elevated WBGT (OR=1.84, 95% CI 1.18–2.86, P<0.01).

CONCLUSION: Hypohydration was not significantly associated with exertional heat illness risk during arduous activity in cool conditions. Significant exertional heat illness risk factors did include low aerobic fitness, previous exertional heat illness and elevated WBGT.

C09

Out with the Ice and in with the Heat: Heat Outperforms Cold Water Immersion for Recovery of Strength after Exercise-Induced DOMS in Healthy Adults

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Purpose: The aim of this study was to investigate the effectiveness of thermal strategies on recovery rate of strength after exercise induced delayed onset of muscle soreness.

Methods: LSBU Ethics: ETH2223-0239.The study used a randomized, parallel group design (N=40 with 10 in each group) over four consecutive test days. Participants performed a single bout of eccentric knee extensions, with baseline and post maximal voluntary contraction (MVC) measurements on a isokinetic dynamometer (HUMAC NORM), followed by a thermal recovery strategy: hot water immersion (HWI;30 min at 42 °C), cold water immersion (CWI;15 min at 9 °C), hot air immersion (HAI; 30 min at 30°C, 30% RH) or control (CON: 30 min at 18 °C, 30% RH). Recovery rate of strength (via MVC), and pain and muscle soreness (via visual analogue scales) was monitored over 72hr (pre exercise, post exercise, post therapy, 24hrs, 48hrs, and 72hrs post therapy). Venous blood samples were collected each session to analyse Interleukin 6 (IL-6), heat shock proteins (HSP72), and Creatine Kinase Muscle-Muscle isoenzyme (CK-MM). Results: HWI returned 85 and 89% of strength back to baseline MVC values at 48hr (284.30 ± 22.04N vs 243.70 ± 25.33N; p= 0.356) and 72hrs (284.30 ± 22.04N vs 256.00 ± 26.12N; p= 0.801) respectively. CON and HAI returned 88% and 89% of strength back to baseline MVC values at 72hrs (303.70±22.04N vs 268.50 ±26.12N; p= 0.314, and 299.70±22.04N vs 268.70±26.12N; p= 0.563 respectively). Whereas, CWI MVC values were still 25% higher than baseline at 72hrs (279.10 ± 22.04N vs 218.80 ± 26.12N; p=0.005). There was no significant difference in the recovery of pain or muscle soreness between groups over time (P >0.05). CK-MM increased from baseline to post-exercise in all groups (p < 0.05). However, HWI caused a significant decrease in CK-MM in comparison to other groups over time (p < 0.05). HSP72 increased significantly after HWI and HAI (1.36±0.11 vs 1.81±0.14 mg/ml and 1.36±0.11 to 1.6±0.14 mg/ml; p = 0.001), while CWI caused a significant decrease (1.36±0.11 vs 0.87±0.10 mg/ml; p = 0.001), with no change in CON (1.21±0.01; p = 0.671). Quadriceps muscle temperature increased with HWI (36.57±1.2 °C vs 38.83±1.3 °C; p= 0.005) and decreased with HAI (37.05±0.5 °C vs 34±1.7 °C; p= 0.05) and CON (36.61±0.9 °C vs 34.78±2.2 °C; p= 0.012). There was no significant difference in HAI (36.05±0.9 °C vs 36.27±0.5 °C; p = 0.444). HWI reduced IL6 after 48 hours (0.54±0.02 vs 0.56±0.02 pg/ml; p = 0.096), whereas CWI reduced after 72 hours (0.61±0.04 vs 0.61±0.03 pg/ml;mp = 0.953).

Conclusion: Hot water immersion was the most effective thermal therapy for returning strength via MVC back to baseline values. This was related to the physiological stimulus that hot water immersion caused on the body (elevation in muscle temperature and heat shock protein 70) and associated upregulation of inflammation (IL6) and low circulating markers of muscle damage (CK-MM) compared to other therapies. Therefore, hot water immersion should be favored for recovery rate of strength. However, all thermal therapies were not effective for reducing pain and muscle soreness.

C10

Effect of a Combined Cooling Intervention on High Intensity Intermittent Cycling Performance and Cognitive Function in the Heat.

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The ability to repeatedly perform high-intensity efforts interspersed with minimal recovery, coupled with optimal cognitive function, is imperative for successful team-sport performance (Spencer, Bishop, Dawson & Goodman, 2012; Williams, 2000). However, both components face impairment when core temperatures reach 38.5°C, which can commonly occur in hot environments (Drust, Rasmussen, Mohr, Nielsen & Nybo, 2005; Schmit, Hausswirth, Le Meur & Duffield, 2017). Therefore, the present study investigated the effect of internal and external cooling on high intensity intermittent cycling performance and cognitive function in the heat.

Twenty-nine male, games players completed a control (CON) and cooling trial (ice slurry & ice collar; COOL) in the heat (33°C, 50% RH) involving a 40-min intermittent cycling protocol consisting of 2 sets of 10 2-min stages (5-s sprint, 105-s active recovery, 10-s rest). Participants completed a battery of cognitive tests, which involved the Visual Search test, Stoop Task, Sternberg Paradigm and RVIP, pre- and post-exercise with physiological and perceptual responses recorded throughout. All data was analysed using a two-way repeated measures ANOVA.

No differences in peak or mean power output were found between conditions (all $p > 0.05$). Rectal (COOL: 37.39 ± 0.59; CON: 37.59 ± 0.56°C, $p < 0.001$) and neck (COOL: 28.87 ± 4.87; CON: 32.82 ± 1.43°C, $p < 0.001$) temperature, as well as heart rate (COOL: 123 ± 40; CON: 127 ± 41 beats·min^{-1}, $p = 0.038$), were found to be lower in COOL. Participants reported feeling better in COOL as well as reporting lower ratings of thermal sensation ($p < 0.001$) and improved comfort ($p < 0.001$). Response times on the number level of the Sternberg Paradigm were quicker during COOL (COOL: 434 ± 77 ms; CON: 437 ± 84 ms, $p = 0.045$) however, over time, the improvement in response times was greater in CON (COOL: 6 ± 3ms quicker; CON: 26 ± 2ms quicker, $p = 0.015$). Response times got quicker over time to a greater extent in CON on the Visual Search complex level (COOL: 15 ± 1ms quicker; CON: 119 ± 31ms quicker, $p = 0.009$). Stroop Task complex level response times were quicker over time in COOL compared to CON (COOL: 48 ± 23ms quicker; CON: 11 ± 18ms quicker, $p = 0.002$). However, no differences were found on the other tests or test levels, or for accuracy of responses (all $p > 0.05$).

The combined cooling intervention led to improvements in some physiological and perceptual responses to intermittent exercise in the heat and minimally influenced cognitive function, as seen through enhanced executive function on the Stroop Task. However, the combined cooling intervention did not affect intermittent sprint performance, which was evidenced through a lack of differences in peak or mean power output. These findings provide information on a practical combined cooling method that can be feasibly implemented in elite sport.

C11

The effect of repeated hot water immersion on cutaneous microvascular function and mean arterial pressure in males of White European and South Asian descent.

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BACKGROUND:

Individuals of South Asian (SA) descent are at an increased risk of cardiovascular disease (CVD) compared to White European (WE) counterparts[1]. This health disparity may be partially explained by impaired vascular function within the SA population[2]. Heat therapy, such as sauna bathing or hot water immersion (HWI), has been shown to improve vascular function[3] and reduce all-cause mortality[4]. However, it is unknown whether populations of distinct racial backgrounds such as WE and SA respond differently to chronic heat therapy. Therefore, we compared the effect of repeated HWI on cutaneous microvascular function and mean arterial pressure (MAP) between individuals of WE and SA descent.

METHODS:

Ten healthy, recreationally active WE and SA males (age: 23 ± 5 vs. 24 ± 2 years; body mass index 25 ± 3 vs. 25 ± 3 kg/m^2, respectively) had forearm and toe cutaneous vascular conductance (CVC) responses during post-occlusive reactive hyperaemia (PORH) and local heating (LH) measured (Pre). Thereafter, 10 sessions consisting of 30 minutes of shoulder-level then 30 minutes of waist-level HWI (39.0°C) over 14 days were completed. For the first (H1) and last (H10) HWI sessions, MAP was measured at rest and during 30-, 45- and 60-minutes of immersion, with forearm and toe CVC responses remeasured within 48 hours of H10 (Post). Two-way mixed-model repeated measure ANOVAs were conducted to investigate the effect of HWI between racial groups.

RESULTS:

Baseline forearm and toe CVC were similar Pre and Post HWI ($p \geq 0.53$), although SA had lower baseline forearm CVC ($p = 0.01$) but similar baseline toe CVC to WE ($p = 0.67$), with no Race*HWI interaction effects ($p \geq 0.16$).

During PORH, forearm and toe peak CVC as a percentage of baseline ($p \geq 0.42$), CVC area under the curve ($p \geq 0.55$) and PORH index ($p \geq 0.44$) were unchanged by HWI. Furthermore, a greater forearm PORH index in SA ($p = 0.03$) was the only racial difference and there were no Race*HWI interaction effects ($p \geq 0.08$).

In response to 42°C LH, forearm ($p = 0.04$) and toe ($p = 0.04$) CVC were elevated following HWI; during 44°C LH toe CVC was greater ($p = 0.02$), whereas forearm CVC was unchanged ($p = 0.12$). There were no racial differences ($p \geq 0.42$) or Race*HWI interaction effects ($p \geq 0.37$) during LH. Resting and throughout immersion, MAP was unchanged by HWI ($p \geq 0.33$) and did not differ between races ($p \geq 0.54$), with no Race*HWI interaction effects ($p \geq 0.39$).

CONCLUSION:

Forearm and toe microvascular reactivity to LH were improved by HWI in individuals of WE and SA descent, however, microvascular responses during PORH were unchanged. Although HWI did not influence MAP, chronic adaptions are purportedly underpinned by repeated acute responses[5],

highlighting longer-term HWI may be required for beneficial reductions in MAP. Despite HWI similarly improving microvascular function between racial groups, these results are particularly relevant for SA individuals given the elevated CVD risk, impaired vascular function and reduced likelihood of meeting physical activity guidelines identified within this population[1,2].

C12

Impact of localised skin cooling of the sacrum on the skin's inflammatory responses to sustained mechanical loading

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Introduction

Pressure ulcers (PUs) are localised skin damage caused by prolonged pressure and shear forces (Kottner et al., 2019). PUs constitute a significant healthcare challenge, with chronic wound treatment costing approximately £8.3 billion annually in the UK. Elevated temperature and moisture levels within and around skin tissues can also increase the risk PUs; this has led to a growing interest in the therapeutic effect of localised skin cooling to maintain skin tissue viability.

Preliminary animal work indicates that local cooling and stimulation of cold-sensitive TRPM8-expressing neurones could modulate the skin's inflammatory responses to acute mechanical stress (e.g. pressure loading) via downregulation of pro-inflammatory cytokines such as TNF-a (Lee et al., 2014). However, the extent to which skin cooling mitigates inflammatory responses to mechanical loading in humans remains unclear. The aim of this study was to investigate how localised cooling can modify in vivo inflammatory responses of the skin to mechanical loading and shearing in a cohort of healthy young adults.

Methods

Ethical approval was granted by the University of Southampton Ethics Committee (ERGO:88984). Twenty-two young adults (25±4y; 71±9Kg; 17±9cm) partook in 3 experimental sessions separated by a minimum of 24 hrs in a randomised cross-over design. During each session, participants underwent a standardised 75-min protocol to cause pressure-induced ischemia and post-occlusive hyperaemia at the sacrum, involving: i) a 10-minute baseline stabilisation with minimal pressure [17.5 mmHg (2.3 kPa)], ii) 45-minute loading phase [60 mmHg (7.9 kPa)], and iii) a 20-minute minimal pressure phase [17.5 mmHg (2.3 kPa)]). Participants' skin over the sacrum was mechanically loaded and unloaded with a custom-built thermal probe, which, depending on the session, was set to either 38°C, 24°C, or 16°C. Skin sebum was collected non-invasively (Sebutape, CuDerm, Dallas, TX, USA) prior to and following each thermal conditions, and used to analyse up- or down-regulation of selected inflammatory biomarkers (TNF-a, IL1-β, IL-6, IL-8 and IFN-γ; Gordon et al., 2024) via extraction techniques optimised by our laboratory (MSD V-PLEX Pro-inflammatory panel 1 (Meso-Scale Discovery, Rockville, MD; Jayabal et al., 2023).

Results

At the time of writing, biomarkers analyses were completed in 5 participants. Preliminary observations indicated a small down-regulation of TNF-a following cooling (-1.3 $pg.mL^{-1}$) but not warming at 38ºC (-0.3 $pg.mL^{-1}$). A similar down-regulation was observed in IFN-g following 16ºC (-6.0 $pg.mL^{-1}$) but not 38ºC (-1.2 $pg.mL^{-1}$). Finally, IL- 6 also appeared to decrease after mechanical loading was applied at 16ºC (pre: 2.4 $pg.mL^{-1}$, 95% CI[0.3, 4.4]; post: 1.2 $pg.mL^{-1}$, 95% CI[0.6, 1.8]), but not at 38ºC (pre: 1.8 $pg.mL^{-1}$, 95% CI[0.4, 3.2]; post: 1.6 $pg.mL^{-1}$, 95% CI[-0.01, 3.2]).

Conclusion

These preliminary data indicated that localised skin cooling may blunt expression of some skin pro-inflammatory cytokines following sustained mechanical loading of the sacrum. Given that these cytokines are involved in the inflammatory cascade associated with the loss of skin integrity and development of PUs, localised skin cooling could offer promising therapeutic applications for the maintenance of skin tissue viability.

Table 1: Summary of concentrations of pro-inflammatory biomarkers of interest measured in skin sebum at the and sacrum before and after mechanical loading. Two distinct temperatures were applied locally to these sites with skin sebum sampled pre- and post-skin insult. N = 5 with data presented as mean with [95% Confidence Intervals]

	16 ºC		**38 ºC**	
	Pre	Post	Pre	Post
IFN-Y (pg.ml^{-1})	14.0 [3.4, 24.6]	8.0 [4.3, 11.8]	10.8 [3.8, 17.7]	9.6 [1.6, 17.5]
IL1-β (pg.ml^{-1})	1.5 [0.6, 2.4]	0.7 [0.2, 1.1]	1.7 [0.4, 2.9]	1.1 [0.3, 1.8]
IL-6 (pg.ml^{-1})	2.4 [0.3, 4.4]	1.2 [0.6, 1.8]	1.8 [0.4, 3.2]	1.6 [-0.1, 3.2]
IL-8 (pg.ml^{-1})	1.1 [0.1, 2.1]	0.6 [0.3, 0.9]	1.2 [0.0, 2.5]	0.9 [-0.1, 1.8]
TNF-α (pg.ml^{-1})	2.9 [1.1, 4.8]	1.6 [0.9, 2.2]	2.2 [1.0, 3.4]	1.9 [0.3, 3.6]

C13

Age- and body site-dependent differences in skin epidermal properties and microvascular density: implications for localised cooling therapy for pressure ulcer prevention

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Introduction

Pressure ulcers (PU) arise from localised damage to the skin through a combination of sustained pressure and shearing forces, costing ~£8 billion a year to treat in the UK (1). Microclimate conditions within and around skin tissues influence its tolerance to mechanical loading, with cooling reducing skin tissue's metabolic demands and increasing its tolerance to mechanical damage (2). This has informed the design of several therapeutic interfaces and surfaces delivering local cooling via microclimate management systems (3). However, evidence underlying their efficacy across different populations remain limited. It is unclear whether interventions should be adjusted based on factors such as age and skin site. This knowledge gap is driven by a lack of normative data on age- and body site-dependent differences in skin epidermal properties and microvascular density, which could modulate the efficacy of localised cooling therapy for PU prevention.

The aim of this study was to characterise age- and anatomical site differences in skin epidermal thickness and microvascular density using optical coherence tomography (OCT), in younger and older adults.

Methods

Ethical approval was granted by the University of Southampton Ethics Committee (ERGO:88984). Twenty-two younger (25±4y; 71±9Kg; 17±9cm) and 19 older adults (65±4y; 70±14Kg; 171±10cm) with no health conditions, underwent an in vivo characterization of epidermal thickness (μm) and vascular density (expressed as a % of tissue comprising blood vessels against the depth of detection) at two skin sites, the sacrum and posterior heel. Skin properties were assessed using an OCT scanner. Vascular density data were analysed using a three-way ANOVA to assess the interaction between blood vessel depth, age, and anatomical site. Epidermal thickness was analysed using a two-way ANOVA to assess the interaction between age and anatomical site.

Results

There was a main effect of depth ($P<0.001$) on vascular density (Fig. 1) and an interaction between depth and the anatomical site ($P<0.001$), but no effect of age on either depth ($P=0.810$) or skin site ($P=0.517$). Post-hoc analyses indicated that peak vascular density in the sacrum (depth 0.4mm) was greater than in the heel (mean difference +4.5%, 95%CI [3.7, 5.2], $P<0.001$). In contrast, peak vascular density in the heel occurred at a more superficial depth (0.15mm) and lower magnitude compared to the sacrum (mean difference -5.5%, 95%CI [-6.3, -4.7], $P<0.001$).

The epidermal thickness of the skin was greater in the heel than the sacrum (mean difference +180.9μm, 95%CI [156.6, 205.4], $P<0.001$, Fig. 2), but there was no effect of age between younger and older groups ($P=0.388$).

Conclusions

Results highlighted an effect of body site, but not age, in skin epidermal properties and microvascular density across two skin regions at risk of PU development. The heel presented a thicker epidermis, and a lower absolute and more superficial microvascular density than the sacrum, which presented a thinner epidermis and higher and deeper microvascular density. Importantly, ageing did not clearly alter the tested skin properties. Altogether, these findings indicated that localised thermal intervention may need to consider variations in epidermal and vascular properties with skin site to optimise the efficacy of skin cooling in maintaining skin tissue viability.

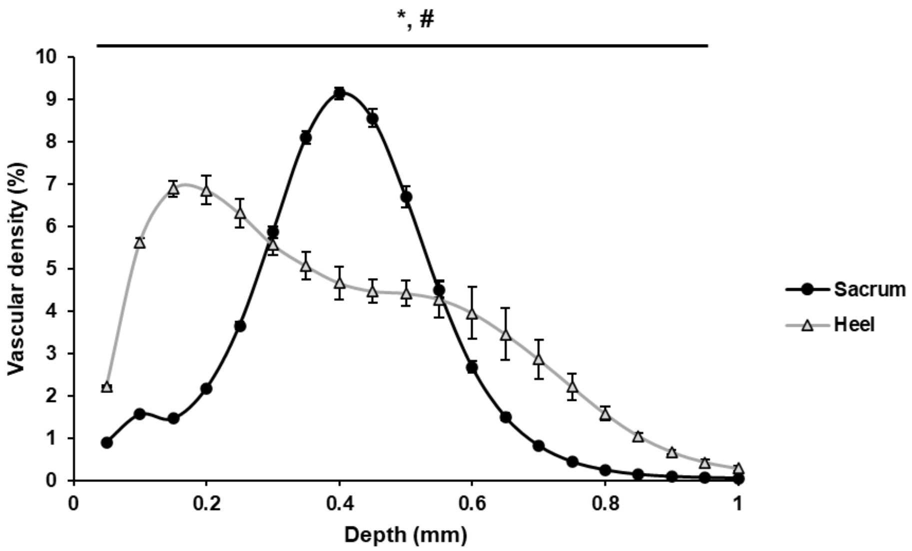

Figure. 1. Characterisation of vascular density plotted against depth in the skin of the sacrum and heel. Data (n=41) are means±SD. *Main effect of depth (*P*<0.05). #Interaction between depth and anatomical site (*P*<0.05).

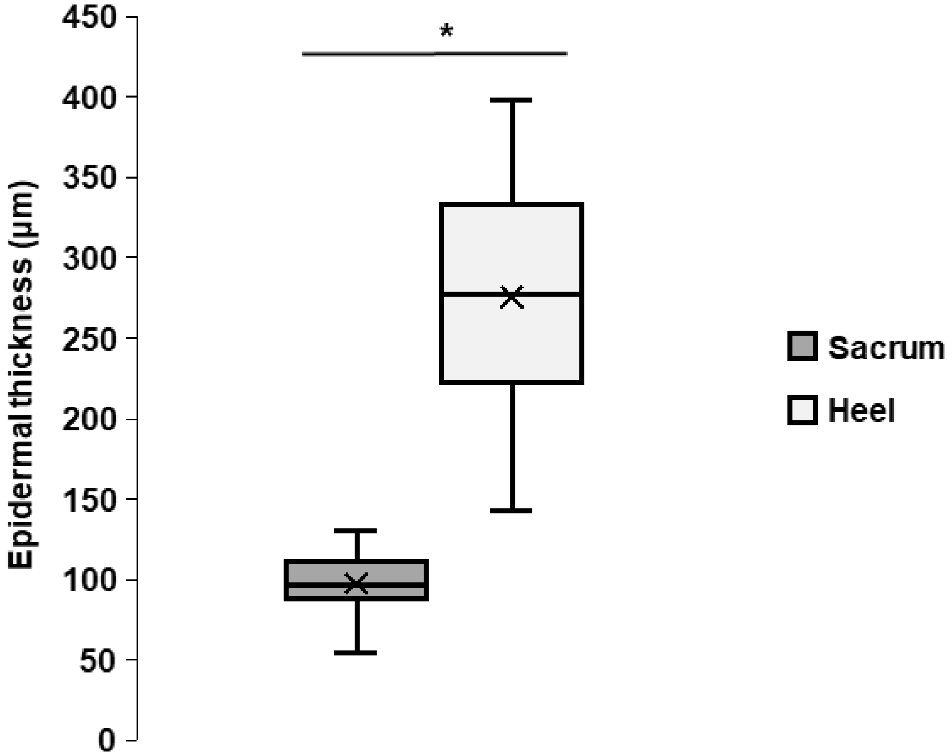

Figure. 2. Differences in epidermal thickness at two different skin sites. Due to technical issues obtaining epidermal thickness measurements, data are for n=25. Box plots show 1st and 3rd interquartile ranges. The solid line within the boxes denotes group means and the x denotes the median. *Main effect of anatomical site (P<0.05).

C14

Preparing for a heat wave and perceived heat illness symptoms during a heat wave in the UK – insights from vulnerable adults

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Introduction: Climate change increasing mean global surface temperature is associated with an increase in the frequency, intensity, and duration of extreme heat events, such as heat waves. Exposure to heat stress poses risk to human health and wellbeing. Heat waves are associated with an increase in excess deaths and heat related illnesses, those with pre-existing health conditions and advanced age being at a heightened risk (Office for National Statistics, 2022; Arbuthnott & Hajat, 2017). The aim of this study was to examine the (1) utilisation and circulation of educational materials, (2) preparedness to experience and manage heat waves, (3) perceived heat illness symptoms in UK residents, particularly heat-vulnerable individuals, following a heat wave, and (4) willingness to adopt heat mitigation strategies in the future.

Methods: 208 participants (148 females and 60 males, aged 18-86 years) completed a self-administered JISC survey within 10 days of the July 2024 heat wave (regional threshold temperatures: 25-28°C; threshold met in 8/11 regions for at least 3 consecutive days; peak temperature=32°C). All respondents confirmed they had been residents in the UK for > 6 months.

Results: The sample included individuals with no known pre-existing health conditions (N=121), clinical conditions (N=41; including Obesity: N=7, Diabetes: N=6, Cardiovascular Disease: N=7, Respiratory Disease: N=15, and Neurological Conditions: N=11), mental health conditions (N=35), and advanced age (N=31; over 65 years). Twenty-one participants reported a combination of clinical conditions, mental health conditions, and advanced age (sample sizes reflect total number of participants with each condition; total sample: N=208).

There was a lack of education to support preparation for a heat wave in healthy participants, only 12% (15/121) accessed Public Health England guidance, and 11% (13/121) were provided with education by their employer. Despite being at a known greater risk, employers rarely provided education to those with a clinical condition (3/41; 7%), mental health condition (4/35; 11%), and the elderly did not widely access the Public Health England guidance (2/31; 6%). Respondents expressed concern for the impact of heat waves on human health and wellbeing (120/208; 58%), despite many feeling prepared to manage a UK heat wave (133/208; 64%). Experience of heat related illness symptoms were reported (including fatigue, feeling thirsty, sweaty, and lightheaded) by participants with clinical conditions (41/41; 100%), mental health conditions (32/35; 91%), and the elderly (30/31; 97%). Willingness to adopt at least one heat mitigation strategy to improve future heat management was high (199/208; 96%), including regularly taking a hot bath (92/208; 44%), regular sauna use (64/208; 31%), using a fan (150/208; 72%), and taking regular breaks (136/208; 65%).

Conclusion: In this sample of a broad demographic of UK residents, acknowledgement of the associated implications and willingness to prepare for heat waves were apparent. Educational materials were rarely encountered, even by those who are more vulnerable. These findings highlight the importance of education circulation by employers and public health organisations to enhance the preparedness of the public to endure heat waves.

C15

Heat wave ahead - combined passive and active heat acclimation to enhance thermal resilience and cardiovascular health in older, overweight adults

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Introduction: Climate change progresses and coincides with increasing prevalences of extreme heat events globally [1]. The threat for heat-related complications is particularly pronounced among vulnerable populations, such as older and overweight individuals [2]. Heat acclimation is known to enhance thermal resilience to heat stress and mitigate adverse effects [3]. Research has mostly focused on benefits of heat acclimation for exercise performance with protocols applying extreme temperatures and high-intensity exercise [4]. However, those protocols do not apply to a broader, especially heat-vulnerable populations. Previous work from our lab demonstrated that passive heat acclimation, despite the mild heat stimulus, enhanced resilience to heat in overweight older adults [5]. Aim: The present study builds on those results and aims to assess a combined passive and active heat acclimation approach, mimicking real-life outdoor temperature scenarios leading up to a heat wave, on thermophysiological and cardiovascular parameters in overweight adults between 60 and 80 years. Methods: The study was approved by the Medical Ethics Committee of MUMC⁺ and it was conducted in accordance with the principles outlined in the Declaration of Helsinki (Fortaleza, Brazil, 2013). 7 women and men (age 70±6 y, BMI 28.7±1.8 kg/m^2) underwent one control week and one week of passive heat acclimation (6h/d, 29-35°C) in combination with low-to-moderate intensity exercise (30min/d cycling, 40% Wmax). Test days T1 and T2 were performed before and after the control week and T3 after the final acclimation day. Each test day consisted of 180-min incremental heat stress test (HST), during which participants were exposed to gradually increasing temperature (28-45°C). Participants arrived fasted in the morning of each test day and rested semi-nude in a recliner during the HST. Thermophysiological (core and skin temperature) and cardiovascular (heart rate, blood pressure) parameters were measured. For the comparison of the physiological variables, two time periods during HST were selected: baseline (28°C, 30-60 min) and heat (45°C, 150-180 min). Outcomes were analysed with two-sided paired t-test between control (ΔT2-T1: pre acclimation) and after the intervention (ΔT3-T2: post-acclimation). Data represent means±SD. Preliminary results: Changes in core temperatures averaged -0.01±0.19°C during baseline at control vs -0.07±0.21°C post-acclimation (P=0.01, Figure 1). During heat, changes in core temperatures averaged -0.06±0.24°C at control vs -0.13±0.18°C post-acclimation (P<0.021, Figure 1). Skin temperatures averaged 33.93±0.53°C and 33.77±0.45°C during baseline (28°C) pre acclimation vs 33.59±0.35°C post acclimation (P<0.001) and during heat (45°C) 37.15±0.44°C vs 37.04±0.38°C pre acclimation vs 37.04±0.37°C post acclimation (P=0.003). No significant changes were observed in systolic and diastolic blood pressure and mean arterial pressure at baseline (28°C) and during heat (45°C) (Table 1). Heat acclimation significantly decreased heart rate during heat (45°C; P<0.001), while no differences were detected during baseline (28°C; P=0.298, Table 1). Conclusions: Preliminary results show that 7 days of combined passive and active heat acclimation significantly enhanced thermoregulation and lowered heart rate during heat stress in older, overweight adults, suggesting a potential reduction of heat-health risks. Further analysis (for powered group size of n=10 participants) at the end of the study is needed to draw definitive conclusions.

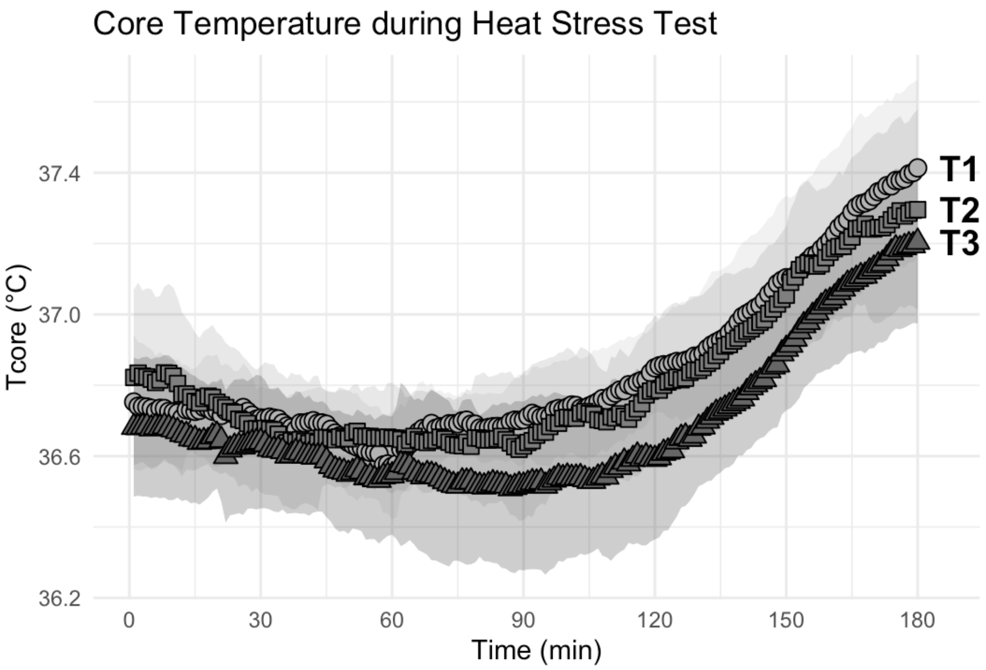

Table 1 Cardiovascular parameters before and after heat acclimation during the heat stress test

	T1	T2	T3	ΔT2-T1	ΔT3-T2	P value
Systolic blood pressure (mmHg)						
Baseline (28°C)	136±15	132±16	122±12	-4±7	-8±9	0.392
Heat (45°C)	128±10	130±12	125±14	1±10	-5±10	0.254
Diastolic blood pressure (mmHg)						
Baseline (28°C)	87±10	82±9	77±4	-5±5	-5±6	0.983
Heat (45°C)	75±9	75±6	73±9	-1±6	-2±8	0.751
Mean Arterial Pressure (mmHg)						
Baseline (28°C)	110±11	105±11	98±6	-5±5	-6±7	0.619
Heat (45°C)	99±9	100±7	97±7	1±7	-3±7	0.4
Heart rate (bpm)						
Baseline (28°C)	60±11	57±8	54±8	-3±7	-3±3	0.298
Heat (45°C)	68±11	69±12	66±12	1±4	-3±5	**<0.001**

Results of two-sided paired samples t-test. Data represent Means±SD. ΔT2-T1: control, ΔT3-T2: post-acclimation.

C16

The estrous cycle phase influences tolerance to exertional heat stroke in mice: Insights into the role of progesterone

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Exertional heat stroke (EHS), the most severe manifestation of heat-related illness, affects males and females equally. We previously observed in a model of EHS that the time to loss of consciousness (LOC) was longer in female compared to male mice. Ovariectomy (OVX) abolished this difference and decreased the variability in time to reach LOC. AIMS. We tested the hypotheses that (i) the estrous cycle (EC) phase, which is the rodent equivalent of the menstrual cycle in humans, would influence the time to LOC in our EHS model and (ii) if progesterone replacement in OVX animals would restore the time to LOC. METHODS: Adult C57BL/6 female mice were implanted with telemetry sensors to measure core temperature (TCORE). Following familiarization, mice exercised in a forced wheel running device inside an environmental chamber set at 37.5°C and 40% relative humidity until reaching LOC. We performed cytological determination of the EC; Estrus (E, n=44) was identified by the predominant presence of cornified epithelial cells at high density, while Diestrus (D, n=30) was identified by predominant presence of leukocytes. To evaluate the effect of progesterone, a separate group of animals underwent OVX surgery, and the control group received a vehicle (OVX-C, n=9) while progesterone was delivered via mini osmotic pump for 21 days (OVX-P, n=6) prior to exposure to EHS. RESULTS: In comparison with the E group, D mice required ~18% less time to reach LOC (E: 192.9 ± 36.1 min; D: 169.5 ± 42.8 min; p=0.01), despite achieving lower maximal running speed (Smax; E: 7.4 ± 1.1 m/min; D: 6.6 ± 1.2 m/min, p=0.004), and similar maximal TCORE (E: 42.20 ± 0.21; D: 42.15 ± 0.21 p=0.30). Progesterone delivery increased the uterus mass, a control variable for the progesterone effects (OVX-C: 18.5 ± 9.4 mg; OVX-P: 34.7 ± 8.4 mg, p=0.005), but did not change time to reach LOC (OVX-C: 130.5 ± 28.1 min; OVX-P: 145.6 ± 40.4 min; p=0.40), Smax (OVX-C: 5.2 ± 0.8 m/min; OVX-P: 6.1 ± 1.2 m/min, p=0.11), or maximal TCORE (OVX-C: 42.07 ± 0.34 °C; OVX-P: 42.03 ± 0.32 °C, p=0.81). In conclusion, mice in the diestrus phase reached LOC faster than those in estrus during heat exposure. Progesterone supplementation in OVX mice did not extend time to LOC in this model. These findings may have implications for heat tolerance in women across different menstrual cycle phases and the potential influence of oral contraceptive use on exertional heat illness risk.

C17

A novel approach to characterise self-fanning behaviour and its energy cost in a cohort of healthy young adults exposed to a hot environment

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Introduction

As global temperatures rise and extreme heat events increase in frequency and severity, there is an ever-growing need to better understand human heat tolerance and adaptation [1]. Behavioural thermoregulation represents humans' first and most effective defence against heat. However, research on cool-seeking behaviours under ecologically-valid heat stress scenarios remains limited [2]. Humans have used manual self-fanning as a cooling intervention for millennia [3], although common (not-empirically-tested) beliefs suggest self-fanning could make one hotter [4]. This could be due to increased metabolic (work) heat production and limited convective cooling. This study aimed to determine the characteristics and energy expenditure (EE) of self-fanning as a cool-seeking behaviour in healthy young adults within a hot environment using a novel methodology.

Methods

Ethical approval was obtained from University of Southampton (ERGOII-72799). A convenience sample of 10 healthy males (20±1y; 78±9kg; 183±8cm) participated in two 55min trials (CONTROL and FAN) consisting of resting exposure to 37.0°C (±0.4°C) and 44% (±6%) relative humidity. In FAN, participants were given a hand-held fan (Figure 1) and instructed to use it freely to offset thermal discomfort. During CONTROL, no fan was provided. The fan was instrumented with an accelerometer (AX6, Axivity, UK) and data (25Hz) analysed (Matlab, Mathworks, USA) to characterise: onset of fanning; total duration of fanning; number of continuous fanning bouts (frequency); and fanning work rate. During both trials, an array of continuous measurements were collected including EE (via breath-by-breath gas analysis), gastrointestinal (core) temperature (Tgi), mean skin temperature (Tsk, 4 sites), forehead Tsk, microclimate (next-to-skin) relative humidity (RHsk, 4 sites), and heart rate (HR). Statistical analysis was performed via a linear mixed-effects model—using a Bonferroni correction factor for post hoc tests—and correlational tests. Data were reported as Mean±SD.

Results

Seven out of the 10 participants engaged with self-fanning. However, these participants displayed a heterogeneous use of this cool-seeking behaviour. Specifically, onset time (mean: 12:30 mm:ss [range: 00:49-30:19]), total duration (mean: 05:54 mm:ss [range: 01:04-17:53]), and fanning bouts (mean: 6 [range: 1-17]), displayed great individual variation. By contrast, work rate (mean: 308 strokes·min^{-1} [range: 205-362]) was consistent. The 7 participants who fanned presented no differences in total EE between FAN vs. CONTROL (433±28 vs. 447±64 KJ; p=0.993). We found no correlation between EE and total (self-fanning) duration (Pearson's r=0.528; p=0.223). Furthermore, time-dependent changes in Tgi, mean Tsk, mean RHsk, and HR did not differ between trials (Table 1).

Conclusions

Our results indicate that, when given the opportunity to engage in cool-seeking behaviour, most of our healthy young participants (7/10) utilised self-fanning to offset thermal discomfort. Substantial individual variability exists in the onset and total duration of self-fanning. However, once engaged, this cool-seeking behaviour occurred at a consistent work rate. Importantly, self-fanning did not meaningfully increase EE, nor did it evoke greater increases in body temperatures than no fanning during heat exposure. Our study provides insights on the potential efficacy of self-fanning as a low-cost, accessible cooling strategy to support perceptual heat tolerance. It also showcases a novel quantitative approach to better study common cool-seeking behaviours under controlled laboratory settings.

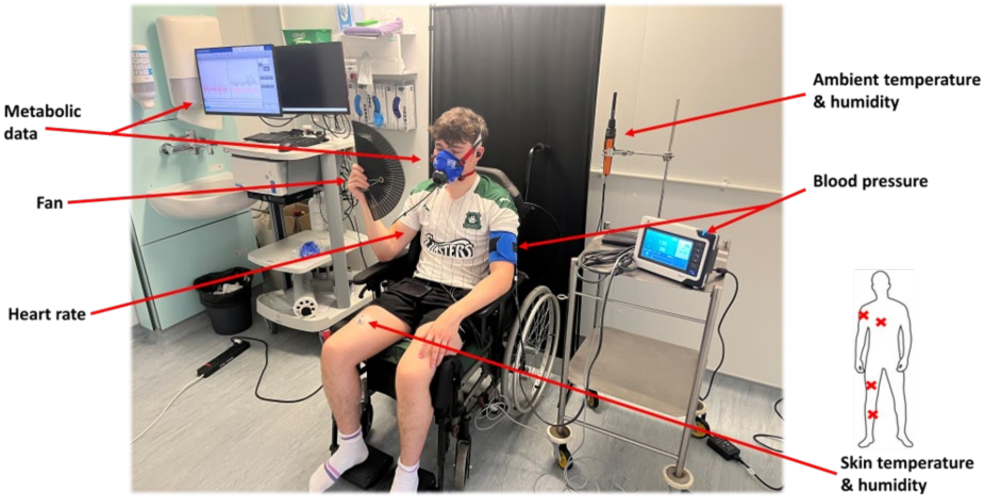

Table 1. Physiological and perceptual responses during FAN and CONTROL trials.

Variable	Timepoint	FAN	CONTROL	*p* values
T_{gi} (°C)	Baseline	37.2 ± 0.3	37.0 ± 0.1	Time: 0.926 Protocol: < 0.001 Interaction: 0.944
	End	37.0 ± 0.3	37.0 ± 0.2	
Mean T_{sk} (°C)	Baseline	32.9 ± 1.06	32.8 ± 0.73	Time: < 0.001 Protocol: 0.078 Interaction: 0.993
	End	35.4 ± 0.31	35.5 ± 0.31	
Mean RH_{sk} (RH %)	Baseline	53.6 ± 9.8	48.0 ± 6.9	Time: < 0.001 Protocol: < 0.001 Interaction: 0.977
	End	85.3 ± 7.7	79.0 ± 11.1	
Forehead T_{sk} (°C)	Baseline	36.0 ± 0.86	35.7 ± 0.62	Time: 0.126 Protocol: 0.850 Interaction: 0.239
	End	36.6 ± 0.43	36.8 ± 0.15	
HR (bpm)	Baseline	71 ± 16	72 ± 12	Time: 0.014 Protocol: 0.218 Interaction: 0.946
	End	77 ± 13	78 ± 10	
Total *EE* (KJ)	Baseline	0 ± 0	0 ± 0	Time: < 0.001 Protocol: 0.2493 Interaction: 0.993
	End	433 ± 28	447 ± 64	

Data reported as Mean ± SD. P values obtained following a linear mixed-effects model. Baseline values represent resting, normothermic values at timepoint 00:00. End values represent end of protocol values at 55:00.

C18

The influence of habitual sauna bathing on flow-mediated dilation in older adults: a pilot study

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Background: Passive heat stress shows promise as an effective strategy to reduce the risk of cardiovascular diseases (CVD) as an alternative or adjunct to exercise and/or medication. Improving function of the endothelium is one of the key targets underlying the reduction in CVD risk.

Aims: We hypothesised that endothelial-dependent dilation, an index of endothelial cell function and nitric oxide bioavailability, is greater in healthy, older adults who regularly partake in sauna bathing compared to those who do not. To test whether sauna provides greater benefits to those with worse baseline vascular impairments, we additionally hypothesised that the improvement to endothelial-dependent dilation in regular sauna users compared to non-users is augmented in a group of older adults with coronary artery disease (CAD).

Methods: Adults aged 50-80 years (n=16) were recruited from the community and all healthy participants were free from CVD as well as medications related to the primary or secondary prevention of CVD. A subset of participants with stable coronary artery disease (CAD) was also recruited (n=8). Informed consent was obtained prior to data collection (Montreal Heart Institute Research Ethics Committee #2017-2179). Endothelial function was measured via the technique of flow-mediated dilation (FMD) using duplex Doppler ultrasound imaging of the brachial artery. The results were compared between groups using a one-way ANOVA performed in SPSS and the critical P value was set at 0.05. When significance was identified, post-hoc tests were performed with a Bonferroni correction.

Results: Baseline brachial artery diameter (P=0.235) and conductance (P=0.812) were not different between groups, but reactive hyperemia SRAUC was lower in CAD patients compared to healthy older adults (P=0.013). However, neither variable significantly influenced FMD when included in the model as a covariate. Additionally, there were no differences between groups for FMD (healthy users: 3.9 [1.6]%, non-users: 4.3 [1.8]% vs. CAD users: 3.1 [2.0]%, CAD non-users: 2.6 [1.8]%; P=0.224) or peak vascular conductance during reactive hyperemia (healthy users: 4.5 [2.2] ml/min/mmHg, non-users: 4.2 [2.2] ml/min/mmHg vs. CAD users: 4.0 [2.2] ml/min/mmHg, CAD non-users: 4.5 [1.0] ml/min/mmHg; P=0.723).

Conclusion: The results of this pilot study indicate that endothelial-dependent dilation (measured via FMD) is not different between groups of habitual sauna users compared to non-users in older adults with and without CAD.

C19

Thermosensory accuracy in a dynamic thermal matching task is linked to depression and anxiety symptomatology

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Introduction: The perception of temperature (i.e., thermosensation) has traditionally been classified as a submodality of exteroception. However, although this modality is the results of stimulation on the body surface, thermosensation also carries information about the physiological state of the skin and the body, often referred to as interoception[1]. Interoception is crucial for our survival but also for the experience of emotions and mental health. Crucially, the body and brain are both involved in thermoregulation processes, such as sweating or shivering[2], and these bodily functions are also closely linked to the experience of emotions such as stress and fear.

Objectives: Although the relationship between changes in body temperature and the experience of emotions has received increasing attention, less is known about the relationship between individual differences in the perception of thermal changes on the body and affective symptoms. Accordingly, here, we focused on the relationship between self-reported depression, anxiety, and stress and thermosensation.

Method: One hundred seventy healthy participants (87 females, mean age 26.297 ± 5.05 years) completed the Depression Anxiety Stress Scale (DASS-21)[3] and a dynamic thermal matching task[4] on hairy (i.e., forearm) and non-hairy skin (i.e., palm). Thermal stimuli were delivered using a thermode attached to a thermal stimulator. The participants' skin was stroked at reference temperatures of 30°C, 32°C or 34°C, and the task consisted of verbally indicating when they felt the same reference temperature again. The task followed a staircase procedure, that is, the temperature was either increased or decreased towards the reference temperature in discrete steps of 2°C. Participants also completed two control tasks: the heartbeat counting task, to measure cardiac interoception, and a classic temperature detection task. The study was conducted in accordance with the provisions of the 1975 Declaration of Helsinki, as revised in 2008.

Results: Our results revealed that higher self-reported anxiety was related to a better performance on the thermal matching task on the forearm (rho = 0.167, $p = 0.028$), while higher depression was related to poorer performance on dynamic and static temperature tasks on the palm (rho = -0.188, $p = 0.014$). Discrepancies between thermosensory accuracy and sensibility measures ('trait prediction error') were related to heightened anxiety (rho = -0.224, $p = 0.003$), in line with previous studies suggesting that alignments of interoceptive dimensions (i.e., accuracy, sensibility, awareness) can predict emotional symptoms, such as anxiety[5]. No significant correlations were found between DASS-21 scores and heartbeat counting accuracy nor between DASS-21 and static thermosensation.

Conclusion: This study suggests that individual differences in thermosensory perception in different areas of the body are associated with self-reported anxiety and depression. Taken together, the present work supports a link between skin-based interoception, specifically thermosensation, and emotions and mental health. As such, the current findings can pave the way for further investigations on the use of thermal imaging as a potential measure of emotional arousal and anxiety. Such insight can shed light on conditions characterized by disorders in the experience of emotions such as alexithymia, which is also characterized by deficits in interoception and thermosensation.

C20

The effect of sauna and cold baths on glucose homeostasis and cardiometabolic health in healthy overweight adults – a study setup

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The rising prevalence of overweight and obesity represents a significant health concern that remains insufficiently addressed by current therapeutic options. Thermal interventions offer a potential alternative for improving metabolic health. Recent studies highlight the positive effects of both repeated heat or cold exposure on glucose homeostasis and cardiovascular health [1-4]. However, the impact of combined heat and cold therapy, with potential amplified/additive effects (or a diminished effect), on the previously observed benefits, remains largely unexplored. While the use of sauna has been shown to have beneficial effects on cardiovascular health [5], its metabolic effects remain largely unstudied.

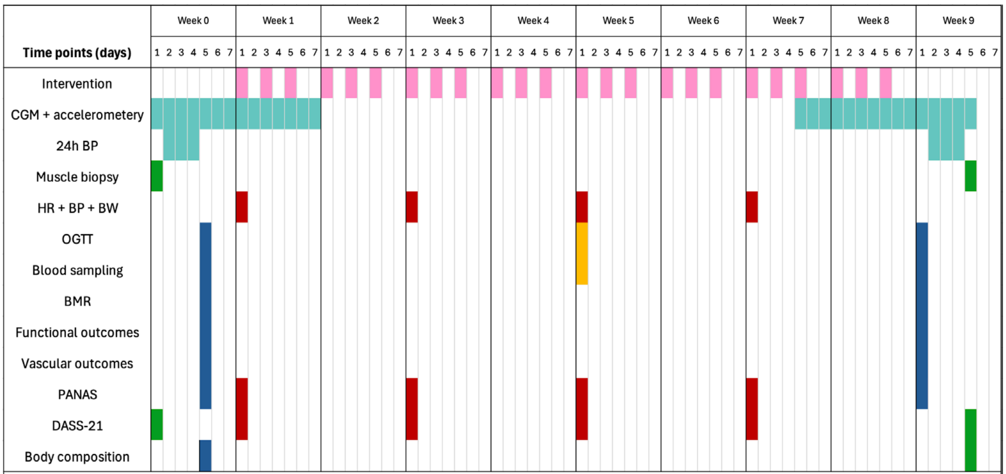
The presented study will assess whether infrared sauna followed by cold-water immersion improves glucose homeostasis in healthy, overweight volunteers. Additional exploratory outcomes including thermophysiological, cardiovascular, metabolic and functional outcomes, as well as inflammatory markers, muscle structure, subjective perception, and mental well-being will be assessed.

A single-arm, within-subject experimental trial will be conducted. Twenty volunteers between 40-75y with a BMI between 27.5-35 kg/m^2 will be recruited. Participants will undergo the intervention three times per week for eight weeks (Fig. 1, pink boxes). After a familiarisation week, each session will consist of two 20-minute sauna exposures (70ºC) (HM-LSE-3 Professional edition, Health Mate, Belgium), followed by 2-minute cold-water immersions (±14ºC) up to the clavicula bones, with a 10-minute rest at room temperature. Three days before and after the intervention, a basal metabolic rate measurement (Maastricht Instruments, Omnical), an oral glucose tolerance test (OGTT) and vascular measurements (pulse wave analysis and velocity (Atcor Medical, SphygmoCor v9), flow mediated dilation (MyLabGamma, Esaote), retinal imaging (Topcon Corporation, Topcon TRC-NW-300) and laser doppler flowmetry (Moor Instruments, moorLAB-HEAT and moorLAB-LDF2) will be conducted (Fig. 1, blue boxes). Additionally, resting heart rate and blood pressure (Omron, M7 Intelli IT), functional outcomes (submaximal cardiopulmonary exercise testing (Lode B.V., Lode Corival CPET) and handgrip strength (Fred Sammons, Inc, JAMAR handheld dynamometer), and a questionnaire on positive and negative affect (PANAS) will be evaluated alongside blood sampling to assess plasma volume, and metabolic (lipid metabolites, renal and liver function) and inflammatory markers.

In the week before and after the intervention period, assessments on muscle structure (m. vastus lateralis biopsy), body composition (doubly-labelled water), and psychological symptoms (DASS-21) will be conducted (Fig. 1, green boxes). Midway through the intervention, an additional OGTT will be performed alongside blood sampling to assess evolution of metabolic and inflammatory markers, and plasma volume (Fig. 1, yellow boxes).

Every two weeks, total sweat loss (bodyweight change), skin (Maxim Integrated Products, iButtons) and core temperature (eCelsius Performance, Body Cap), heart rate (Polar Electro, H10), blood pressure, subjective perception (e.g. ASHRAE-55 7-point VAS), and mental well-being will be monitored during exposure (Fig. 1, red boxes). Moreover, before and after the intervention, glucose (Abbott GmbH & Co, FreeStyle Libre Pro) and physical activity (ProCare BV, Actigraph wGT3X-BT) levels will be continuously tracked over two weeks, and a 24-hour blood pressure measurement (Omron M7, CEMEX) will be conducted (Fig. 1, turquoise boxes).

Preliminary data from pilots and first participants will be presented during the conference.



CGM = Continuous Glucose Monitoring; 24h BP = 24 hour blood pressure measurement; HR = Heart rate; BP = Blood pressure; BW = Bodyweight; OGTT = Oral Glucose Tolerance Test; BMR = Basal Metabolic Rate; PANAS = Positive and Negative Affect Scale; DASS-21 = Depression Anxiety Stress Scale

C21

An inter-disciplinary review of the applications and models of skin wetness perception research and associated experimental methods

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Introduction

Perceiving wetness on the skin because of sweating, or during contact with fluids, wet solids or moist air, is a common experience that plays a key role in skin health, comfort, and performance [1][2] . A greater understanding of the sensorial mechanisms underlying wetness perception is sought in textile engineering, built environment, cosmetics, medical device innovation, and virtual reality [3]. However, experimental and methodological approaches to study wetness perception, and the associated theoretical models, may vary greatly across fields of application. Hence, this paper aimed to undertake an inter-disciplinary systematic review of the applications and models of skin wetness perception research and associated experimental methods.

Methods

Following PRISMA guidelines, we performed a systematic search and screening of publications in English from Jan 2014 to Nov 2024 using Web of Science (n=151), PubMed (n=1733), Scopus (n=602), EBSCOhost (n=154). After removing duplicates (n=364), 97 full-text original research papers were included in the review based on two primary criteria: a) presenting a participant-provided measure of wetness perception (e.g. self-report on a scale) OR b) investigating a mechanism relevant to skin wetness perception (e.g. changes in thermal behaviour because of experimental manipulation of skin wetness) (Fig. 1). Co-occurrence mapping analysis using VOSviewer was performed to identify keyword clusters within the selected papers.

Results

Of the 97 analysed articles, 65% met criterion a only (i.e. self-reports of wetness perception); 8% met criterion b only (i.e. mechanism relevant to skin wetness perception); and 27% of papers met both criteria. The 97 articles covered different fields of application (Fig. 2), namely: “textiles, clothing, wearables” (38.5%), “human physiology” (36%), “haptics and visuo-haptics interactions” (14.5%); “virtual reality” (7%); and “cosmetics (4%).

Across all selected studies, the experimental methods commonly used included detection threshold tests, subjective scales, skin hydration and microclimate humidity recordings. Notably, while several studies examined either temperature thresholds related to moisture and dry touch, or mechanisms of air humidity sensing, no study directly compared wetness sensing mechanisms between those modes of interaction (wet material vs. moist air).

When considering studies meeting criterion b, most of the available evidence indicated that thermal (e.g. changes in skin temperature) and touch cues (e.g. friction) contribute the most to wetness perception (Fig. 3).

Conclusion

This systematic review has highlighted that wetness perception research spans several fields, although the majority concerns “textiles, clothing, wearables” applications, and leverages self-reports of perception. The review has also evidenced differences in the methods being used to assess wetness perception across fields, as well as a lack of investigations directly comparing modes of interaction with wet stimuli (solid, fluids, gases). Future research should develop a comprehensive, interdisciplinary model that accounts for different sensory inputs and contact modalities. Such efforts will enhance multi-field applications in skin health, comfort and performance, ultimately improving multisensory human-environment interactions.

Fig. 1. PRISMA flow chart

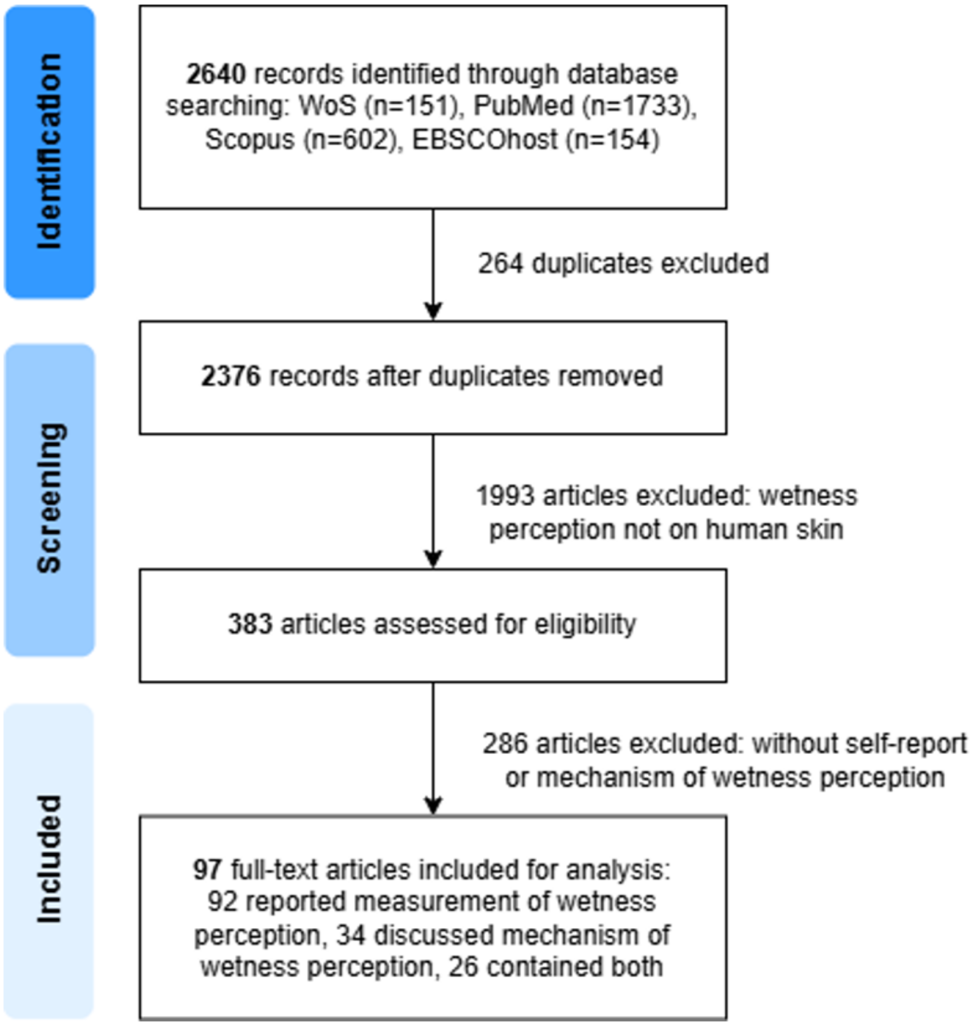


Fig. 2. Proportions of papers met each criteria and covers different application fields

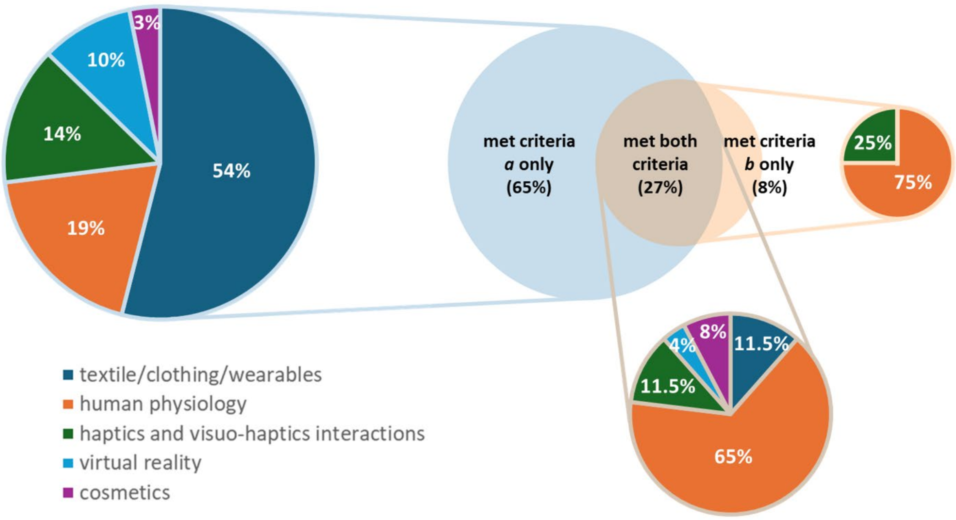
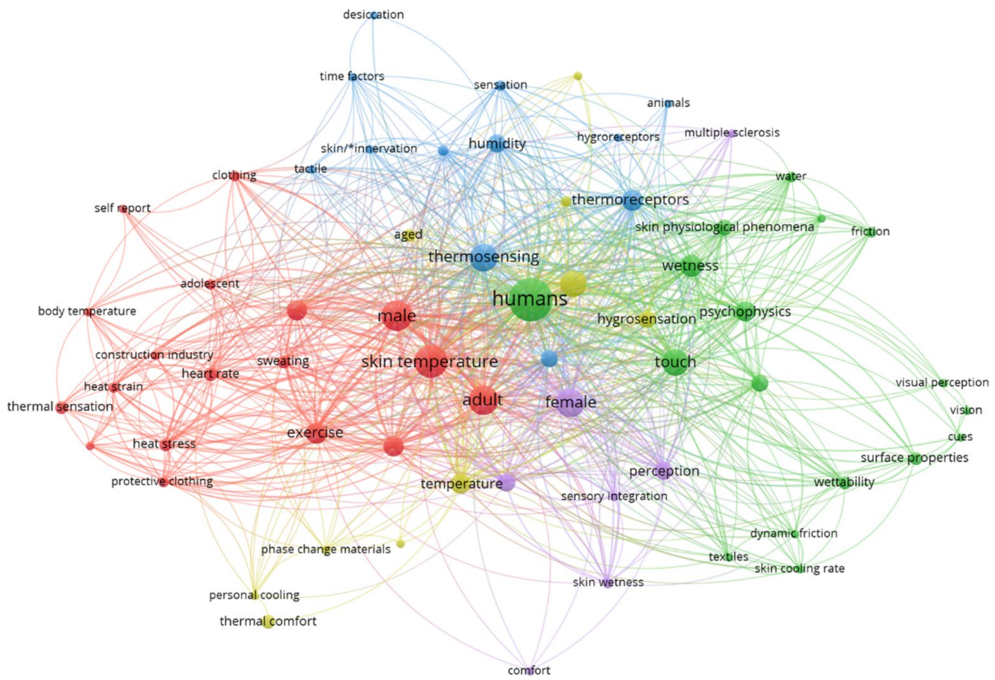


Fig. 3.Co-occurrence mapping analysis using VOSviewer highlighting keyword clusters within the selected 97 papers. The size-dependent clusters evidence areas of importance associated with the mechanisms underlying wetness perception, such as "skin temperature" and "touch".



C22

Individual variability in clothing thermal behaviour: a multidisciplinary review of physiological and ethnographic literature

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Introduction

Behavioural thermoregulation is understood to be a powerful and accessible component of human temperature regulation; crucial in increasingly extreme environmental conditions for maintaining health and facilitating safe access to physical activity. Choice of clothing has been shown to be an effective tool for behavioural thermoregulation which can be utilised by all. However, additional influences such as cultural or psychological factors may result in clothing behaviours contradictory to those which best facilitate heat exchange with the environment. Understanding the various factors additional to thermoregulation which influence clothing behaviour is key for identifying and understanding populations that could be at greater risk of adverse health events or limited access to exercise due to these factors. This review aims to combine current understanding of the individual physiological variables and mechanisms which underpin behavioural thermoregulation, with the additional dimension of ethnographic research into the cultural and psychological influences which may impact clothing behaviour.

Methods

A systematic review of physiological research was conducted in PubMed and Web of Science databases (Figure 1), before a modified keyword string to seek ethnographic research was used in Google Scholar. Outcomes and arising themes from the systematic review guided selection of ethnographic articles from the Google Scholar search output to add an additional dimension to the individual variables identified in physiological research. Additional individual variables represented in qualitative research were then identified from the remaining articles.

Results

The physiological search resulted in 164 studies, after screening 31 studies were included, and analysis of these studies is 50% complete at the time of writing. Screening of identified ethnographic studies is still in progress. Preliminary evaluations of physiological studies have identified variables affecting behavioural thermoregulation such as sex, age, and broadness of range of thermal comfort zone. Provisional ethnographic literature screening has also investigated variables such as age and sex, with additional consideration of subgroups such as transgender populations, and how gender affirming clothing choices may influence thermoregulation. In addition to this, the ethnographic literature has investigated variables such as culture and lifestyle which has not yet been discussed in the physiological studies included in the review.

Conclusion

Preliminary evaluation of physiological and ethnographic literature indicates that the inclusion of ethnographic studies can provide additional insight into individual variables which may impact behavioural thermoregulation. This review has identified some factors represented in both physiological and ethnographic studies such as sex and age, whilst other factors such as culture and lifestyle have so far only been represented by ethnographic studies. Future research into clothing thermal behaviour should adopt a multidisciplinary approach, integrating both physiological and ethnographic studies to provide a more holistic understanding of the multitude of factors which may influence the clothing behaviour of different populations to varying extents. This is crucial for identifying populations which may be at greater risk of adverse health events or limited access to physical activity due to climate change, and potential interventions which could be implemented to support these populations.

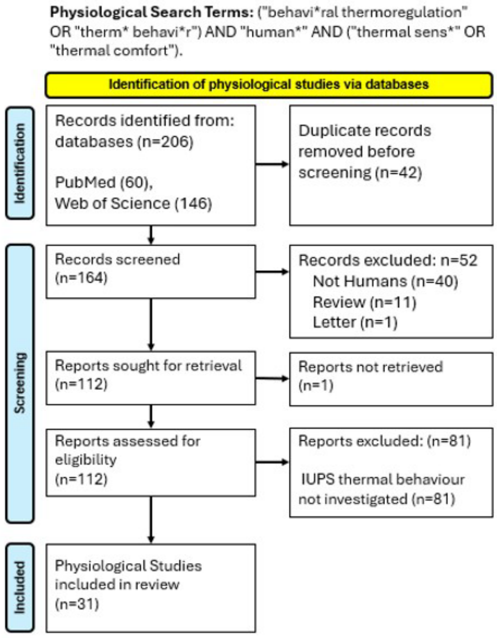

Figure 1. PRISMA flow diagram for physiological searches. *Reports were excluded where they did not investigate a thermal behaviour as defined by the IUPS glossary of terms (2001).*

C23

Thermoregulation and mental health in Parkinson's disease: uncovering an under-explored connection.

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Parkinson's Disease (PD) is widely known for its motor symptoms, but non-motor symptoms including temperature dysregulation significantly impact quality life of people with PD. PD can disrupt temperature regulation causing issues in abnormal sweating or changes in temperature perception (Coon & Low, 2018). Previous research suggested a link between temperature dysregulation and mood disturbances such as depression and anxiety, as thermoregulation and temperature perception are related to emotional processing and interoception (i.e., the perception of the physiological state of the body) (Crucianelli et al., 2024; Crucianelli & Ehrsson, 2023). Nevertheless, the relationship between thermoregulation dysfunction and neuropsychiatric disturbances including mental health symptoms in PD remains unexplored.

A total of 222 patients diagnosed with PD (Mean age = 62.62 years, SD = 7.26), participated in this cross-sectional study to examine the relationship between thermoregulation dysfunction and neuropsychiatric disturbances in patients with PD, specifically focusing on depression, anxiety and apathy. Clinical evaluations included the Scales for Outcomes in Parkinson's Disease for Autonomic Symptoms (SCOPA-AUT) to assess autonomic dysfunction including thermoregulation, the Hamilton Depression Rating Scale (HDRS), the Hamilton Anxiety Rating Scale (HARS), and the Apathy Evaluation Scale (AES). Cognitive function was measured using the Montreal Cognitive Assessment (MOCA), and motor symptoms were assessed using the Unified Parkinson's Disease Rating Scale (UPDRS).

Descriptive statistics revealed a mean disease duration of 10.26 years (SD = 4.39) and a mean Levodopa Equivalent Daily Dose (LEDD) of 1012.38 mg (SD = 458.34). Spearman's correlation analysis showed a significant positive relationship between thermoregulation dysfunction (SCOPA-AUT-thermo scores) and both depression ($\rho = 0.269$, $p < 0.001$) and anxiety ($\rho = 0.312$, $p < 0.001$). These results suggest that increased autonomic dysfunction, particularly thermoregulatory dysfunction is associated with higher levels of depression and anxiety. However, no significant correlations were observed between thermoregulation dysfunction and apathy ($\rho = 0.055$, $p = 0.488$) or cognitive function (MOCA) ($\rho = 0.058$, $p = 0.485$), indicating that thermoregulatory dysfunction does not directly influence apathy or cognitive performance.

Additionally, a strong positive correlation was observed between depression and anxiety ($\rho = 0.811$, $p < 0.001$), which is consistent with previous research indicating a strong link between these two mood disorders in PD (Coon & Low, 2018). Moderate correlations were also found between depression and apathy ($\rho = 0.267$, $p < 0.001$), as well as anxiety with apathy ($\rho = 0.192$, $p = 0.007$). Cognitive function was negatively correlated with apathy ($\rho = -0.158$, $p = 0.040$), suggesting that higher levels of apathy are associated with poorer cognitive performance.

Our findings suggest that temperature dysregulation in PD may significantly influence mood disturbances, particularly depression and anxiety, but does not appear to have a direct relationship with apathy or cognitive decline. This study highlights the importance of addressing thermoregulation dysfunction in the management of non-motor symptoms in PD. Future research should further explore the mechanisms linking autonomic dysfunction and mental health to develop targeted interventions aimed at improving patient overall well-being.

C24

Impact of Repeated Heat Therapy on Glucose Tolerance in South Asian and White European Populations

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Background

Individuals of South Asian (SA) descent are at an increased risk of type 2 diabetes (T2D) and metabolic dysfunction compared to their White European (WE) counterparts[1]. Heat therapy, such as hot water immersion (HWI), has been purported to induce health benefits whilst meta-analyses show equivocal results regarding glycaemic control in various populations[2]. No study has investigated whether populations of distinct racial backgrounds exhibit different glucose tolerance responses following repeated heat therapy. This study investigated the effect of repeated HWI on glucose tolerance in SA and WE individuals using an oral glucose tolerance test (OGTT).

Methods

Following Loughborough University ethical approval and written informed consent, ten WE and ten SA, recreationally active males (mean (SD) age 23 (5) vs 24 (2) years; BMI: 25 (3) vs 25 (3) kg/m^2, respectively) completed an OGTT before (PRE) undergoing 10 sessions of 60-minute (30-minute shoulder-level; 30-minute waist-level) HWI (39 °C) over 14 days. The OGTT was repeated between 24 and 48 hours of the final HWI session (POST). Capillary glucose concentrations were measured fasted and at regular intervals up to 2 h following a 75 g oral glucose load[3].

A mixed design ANOVA assessed the effects of chronic HWI on glucose tolerance, peak [glucose] and area under the curve (AUC) between racial groups, with Bonferroni corrected post hoc pairwise comparisons to examine within- and between-race differences.

Results

For glucose tolerance, there was no significant main effect of condition, race or condition × race interaction (all $p > 0.05$). However, a significant condition × time × race interaction ($p < 0.001$) indicated that HWI affected the time course of the [glucose] responses to HWI differently between SA and WE individuals. Post hoc analysis revealed that in PRE-HWI, SA individuals had higher [glucose] than WE at 30 min ($p = 0.035$). During POST-HWI, SA exhibited higher [glucose] than WE at 60 min ($p = 0.005$). Within-race comparisons showed that SA experienced reductions in [glucose] POST-HWI at 15 min ($p = 0.011$) and 30 min ($p = 0.019$) compared to PRE-HWI, while WE individuals showed no significant within-group changes ($p > 0.05$).

For peak [glucose] and AUC, there was no significant main effect of condition, race or condition × race interaction (all $p > 0.05$).

Discussion

Heat therapy may influence the time course of glucose responses in SA individuals, however, the absence of changes in peak [glucose] and AUC suggests that these effects may not translate to overall improvements in glucose tolerance. The observed reductions in early postprandial [glucose] in SA individuals could indicate subtle alterations in glucose handling, but the lack of similar changes in WE individuals suggests potential racial differences in metabolic adaptations to heat therapy. These differences may be influenced by variations in insulin sensitivity and/or hormonal responses[4].

C25

Exercise thermoregulation during prolonged swimming relative to critical speed in multiple sclerosis patients: A case study feasibility

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Background: When individuals with multiple sclerosis (MS) engage in moderate-intensity exercise, thermoregulatory dysregulation can occur, leading to negative clinical outcomes and early cessation [1]. Exercising in cool water temperatures can reduce the onset of overheating and allow for obtaining the health benefits of high intensity continuous lactate threshold training, that may include enhanced myelination and neuroprotective and metabolic benefits for individuals with MS [2,3]. While critical swimming speed (CSS) is an index for endurance performance and corresponds to lactate threshold in healthy swimmers [3], its relevance to the MS population remains unclear.

Objective: To examine thermoregulatory responses during a 30-min swimming session (T30) in cool water at maximum (100%) CSS in MS patients. Actual observations and modelled predictions were evaluated.

Methods: Six adults (55.8 ± 8.0 years, 2 females) with low-to-mild disability MS performed a 30-min steady-state swimming trial in cool water of 26 °C (ambient temperature: 24 °C, 55 % relative humidity). Exercise intensity was set to 100% of CSS, which was calculated from timed maximum effort, over distances of 50m, 100m, and 200m freestyle. Skin temperatures (Tsk), absolute heart rate (HR), and percentage of maximal heart rate (%HRmax) were continuously recorded. Tympanic temperature (Tty), blood lactate (BLa), thermal sensation (TS), and comfort (TC), and rating of perceived exertion (RPE) were measured pre- and post- swimming. A one-way ANOVA for repeated measures was conducted for multiple comparisons with post hoc analysis, a paired t-test and effect size (ES) for pre- and post-measurements at $p<0.05$. The validated Health Risk Prediction Model (HRP) was utilized to describe heat balance and brain temperature.

Results: Four out of six volunteers successfully completed the entire swimming trial (T30), while one subject terminated prematurely after ~20 min and the other after 5 min. Swimming intensity of 98.2 ±2.6% CSS (0.46±0.22m/s^{-1}) significantly increased BLa from resting values of 2.73 ± 0.5 to 4.98 ± 1.48 mmol/l and RPE from "very light" to "somewhat hard" ($p<0.05$) (Table 1). Cardiac work remained stable during T30 for HR and HRmax%, 125±17 bpm and 84±2%, respectively ($p>0.05$) (Fig. 1). Thermoregulatory changes were observed, such as reduced Tty after swimming (~1 °C, $p<0.05$), while Tsk remained unchanged at ~27°C ($p>0.05$). Improvements to TS from "cool" to "neutral" and TC from "slightly uncomfortable" to "comfortable" were observed at the end of the trial. HRP showed a sharp reduction in brain temperature, a stable mean Tsk ~27°C, and an extent increase of blood and body core temperatures (Fig. 2).

Conclusion: Prolonged high intensity swimming in cool water temperatures at lactate threshold resulted in mild reduction of tympanic temperature that accompanied cardiometabolic and thermoregulatory patterns similar to healthy swimmers [4,5]. Additionally, CSS appears to be a valid and practical coaching tool for endurance testing and prescription of therapeutic swimming for individuals with MS.

Table 1. Tympanic Temperature, blood lactate, blood pressure (Mean±SE) and thermal perception and RPE (Median±SE), * $p<0.05$

	PRE	POST	P-VALUE	ES
Ttymp	36.9±0.1	35.8±0.3	0.007*	0.809
BLa (mmol/L)	2.7±0.2	4.9±0.6	0.011*	0.755
Syst (mm Hg)	119±4.5	115±2.8	0.520	0.087
Diast (mm Hg)	74±3.3	78±2.3	0.100	0.449
TS (7-point scale)	-1.5± 0.3	0±0	0.004*	0.833
TS (6-point scale)	2±0.2	3±0	0.001*	0.907
TC (4-point scale)	2±0.4	1±0	0.001*	0.907
RPE (10-point scale)	1±0.6	4±0.3	0.017*	0.710

Figure 1. Cardiac (a) and superficial thermal responses (b) based on actual observations (filled circles) and HRP predictions for one participant (dashed line with open circles) during 30-min swimming in MS individuals (Mean±SE) (p>0.05)

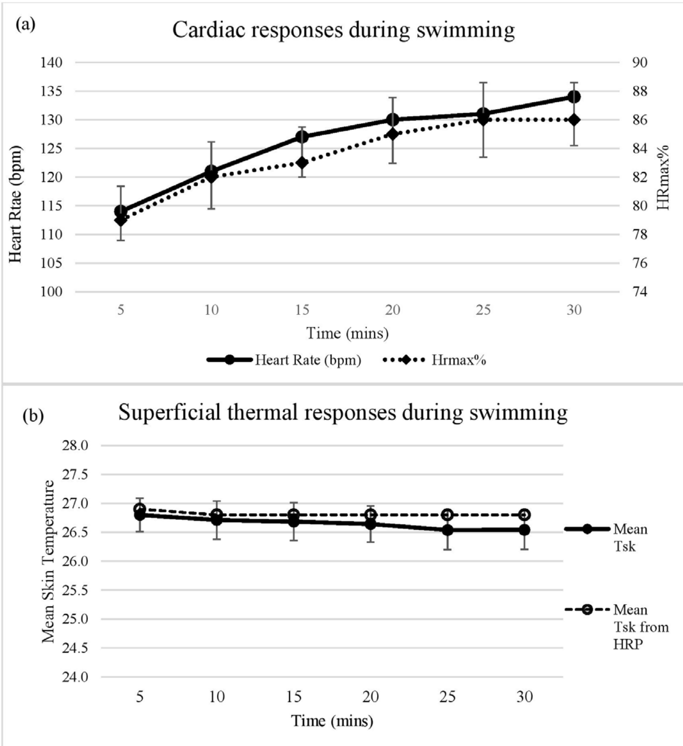


Figure 2. Thermoregulatory responses for one participant based on HRP predictions for Brain temperature (a), Skin Head Temperature (b), Blood Temperature (c), Internal Organs Temperatures (d), Shivering (e), and Metabolic Rate (f) during 30-min swimming in MS individuals with start at 0.2 and end at 0.7 hour.

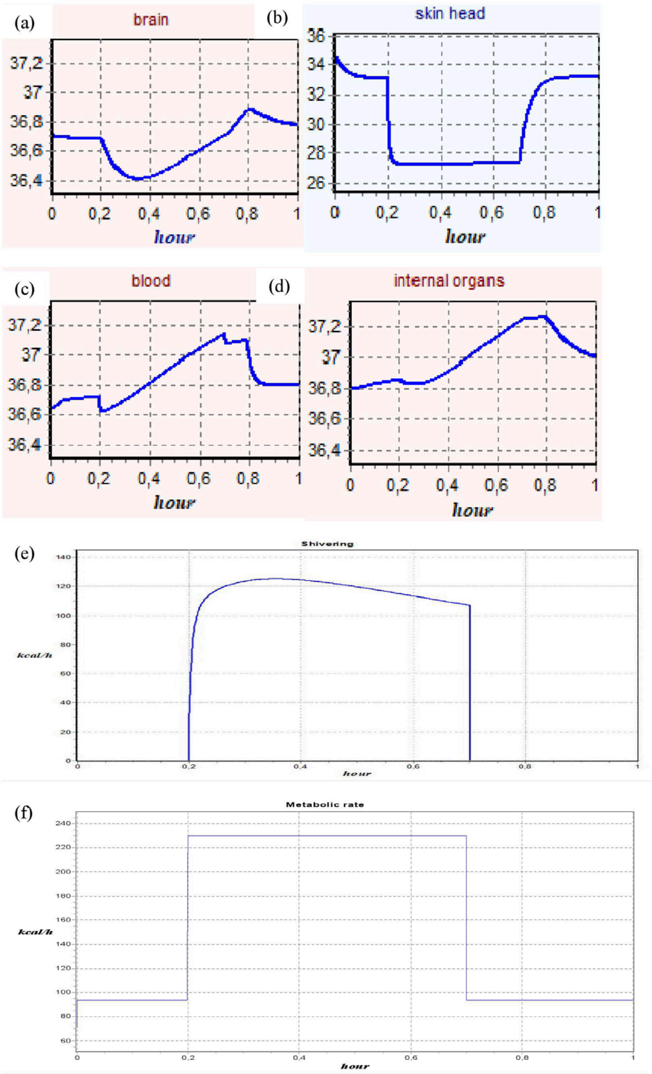
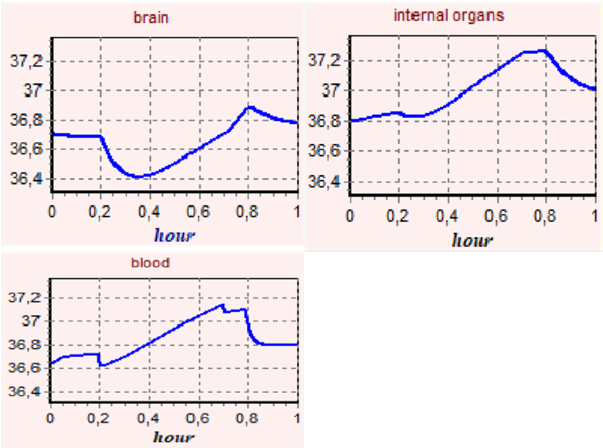


Figure 3. Thermoregulatory responses for one participant based on HRP predictions for Brain temperature (a), Internal Organs Temperatures (b), Blood Temperature (c) during 30-min swimming in MS individuals with start at 0.2 and end at 0.7 hour.



C26

Improvised Prehospital Methods to Reduce Physiological and Perceived Cold Stress in Humans

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Background

To reduce morbidity and mortality from cold exposure it is vital to develop simple prehospital methods that can be improvised and used immediately by first responders and casualties to maintain body temperature and prevent hypothermia. Building membrane and hot water bottles can be improvised in low-resource environments, for example, salvaged from destroyed buildings after natural disasters. Wrapping casualties in vapour-proof barriers, such as foil blankets or polythene survival bags, is a common pre-hospital method, although over time casualties become damp which exacerbates body cooling. Hot water bottles reduce body cooling in animals receiving anaesthesia; however, their effectiveness in reducing cold stress in humans remains to be established. Therefore, this study determined the effectiveness of barrier wraps constructed from vapour-proof foil blanket and vapour-permeable building membrane, with and without three improvised 1-litre hot water bottles, to reduce cold stress of no protection in a cold environment.

Methods

The study received a favourable ethics opinion from the School of Psychology and Sport Science Academic Research Ethics Committee and written informed consent from all participants. Fourteen young healthy participants (10 men, 4 women) completed six conditions: 1. No protective barrier wrap in 26°C, 2. No protective barrier wrap in 10°C, 3. Vapour-permeable building membrane barrier wrap in 10°C, 4. Building membrane barrier wrap plus three 1-litre 73°C hot water bottles in 10°C, 5. Vapour-proof foil blanket wrap in 10°C, 6. Foil blanket wrap plus three hot water bottles in 10°C. All conditions were 20 min and completed in an environmental chamber, whilst participants lay supine, dressed in shorts, t-shirts, socks, and trainers. Cold stress was quantified by thermometry (core (Tc) and mean skin temperature ($\overline{T}sk$)), indirect calorimetry (metabolic heat production (H)), and subjective thermal judgement scales. The data were analysed by ANOVA and Tukey's tests. Post hoc Tukey's tests are presented in the text as mean differences [95% confidence interval].

Results

No differences were detected in physiological and perceptual responses between the building membrane and foil blanket barrier wraps (Interactions: Tc $P = 0.74$, $\overline{T}sk$ $P = 0.19$, H $P = 0.87$, thermal sensation $P = 0.36$, thermal comfort $P = 0.29$, thermal tolerance $P = 0.09$). Compared with no protection, participants wrapped in barriers had 5% higher $\overline{T}sk$ (1.2°C [1.0, 1.5]), 18% lower H (-12 W·m^{-2} [-15, -8]), 46% higher thermal sensation (1.3 [0.7, 1.9]), 42% higher thermal comfort (-0.8 [-1.2, -0.5]), and 54% higher thermal tolerance (-0.9 [-1.2, -0.6]). There were no detectable differences in $\overline{T}sk$ (-0.1°C [-0.2, 0.1] and H (1 W·m^{-2} [-1, 3]) between barriers alone and barriers with hot water bottles. However, participants wrapped in barriers with hot water bottles felt warmer (67% higher thermal sensation; 1.0 [0.5, 1.5]), more comfortable (45% higher thermal comfort; -0.4 [-0.7, -0.2]), and better able to tolerate the cold environment (50% higher thermal tolerance; -0.9 [-1.6, -0.3]) than when wrapped in barriers alone.

Conclusion

Barrier wraps constructed from building membrane were as effective as foil blankets in reducing physiological and perceived cold stress, and adding hot water bottles further reduced perceived but not physiological cold stress.

C27

Efficacy of continuous assessment of thermal perception during fluctuating temperatures and unpredictable thermal scenarios

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INTRODUCTION: Thermal sensation and thermal comfort scales are widely used in human physiology research to quantify human thermal perception during different thermal interventions or in response to varying behavioural modifications. Much of the categorical terminology of Gagge and colleagues' seminal early work from the 1960s persist (e.g., sensation: cold, cool, neutral, warm, hot; comfort: comfortable, slightly uncomfortable, uncomfortable), and today, are evaluated using different Likert and/or visual analogue scales. However, a consistent feature of all thermal perception testing to-date, is that perceptual data is collected at discrete timepoints (e.g., 1, 3, 5, 10, or 30 minute intervals). Consequently, discrete timepoints offer poor temporal resolution, particularly when perceptual shifts in sensation and comfort are transient and unpredictable. Therefore, our objective was two-fold: 1) to develop an efficacious tool to continuously measure thermal perception; and 2), to explore the continuous thermal perceptual patterns during fluctuating and transient ambient temperatures at rest. METHODS: Fourteen healthy participants (7 female and 7 male; 30±4 years, 1.9±0.2 kg/m^2; matched for age, body mass index, and hours of moderate physical activity/week) visited the laboratory on two separate days within the same week, and underwent 30 minutes of transient fluctuations in ambient temperature (ranging from 15 to 35 °C) in a repeated measures blinded design. Participants were asked to continuously monitor their thermal sensation and comfort, and utilize the newly developed perceptual slider tool, to reflect their sensation and comfort. Following ethical consent, background questionnaire and familiarization with the perceptual slider tool, participants were instrumented with skin temperature thermistors and skin heat flux sensors on the hand, lower back and calf, to calculate mean skin temperature and mean skin heat flux. Accuracy (in the context of ambient temperature) was assessed using repeated measures correlations (Rrm) and repeatability (across both thermal profile tests) was assessed using linear regression analysis. Mixed effect modeling was used to explore the variance of predictors on thermal sensation and comfort. RESULTS: Across a fluctuating temperature profile, the perceptual slider tool demonstrated 1) high between-day repeatability and accuracy of thermal sensation (R^2=0.85, $P<0.001$; Rrm=0.85, $P<0.001$, respectively); and 2) moderate repeatability and accuracy of thermal comfort (R^2=0.70, $P<0.001$; Rrm=0.56, $P<0.001$, respectively). Both mean skin heat flux (Rrm=-0.61, $P<0.001$; Rrm=0.37, $P<0.001$) and mean skin temperature (Rrm=0.43, $P<0.001$; Rrm=0.11, $P=0.004$) were significantly associated with thermal sensation and comfort responses, respectively. Sex, age, body surface area-mass ratio and hours of moderate physical activity/week were not significant predictors of either thermal sensation or thermal comfort. CONCLUSION: When perceptual shifts in sensation and comfort occur, due to variations in ambient temperature, the continuous perceptual tool demonstrates high accuracy and between-day repeatability. At rest, the hierarchical associations with thermal perception (i.e. in order of from most significant) are ranked as ambient temperature, mean skin heat flux and mean skin temperature. By continuously measuring perceptual metrics, we will be able to better understand the interplay between psychophysical and physiological relationships of sensation and comfort – with an overarching purpose to help design more efficient and efficacious thermal strategies for the future.

C28

The impact of hair on local skin wetness perception at the underarm during static and dynamic applications of cold-wet stimuli

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Introduction

Experiencing wetness on the skin from sweating or contact with fluids has been repeatedly shown to induce thermal discomfort, which is a critical trigger of behavioural thermoregulation (Filingeri and Havenith, 2018, Gagge, 1937). An example is the common experience of wetness at the underarm resulting from thermal or psychogenic sweating. Millions of people apply antiperspirant deodorant products to the underarm to minimise this negative experience (Watkinson et al., 2007). Due to the lack of hygroreceptors, humans integrate thermal and mechanical inputs arising from the presence of moisture on the skin to perceive wetness (Filingeri and Havenith, 2015). Whilst our understanding of the neurophysiology of skin wetness perception (WP) is expanding (Typolt and Filingeri, 2020). There is limited research on how the structure of the skin, such as the presence of hairs, impacts local WP. This study aimed to investigate the impact of hair on local skin WP at the underarm to inform the design of antiperspirant deodorants.

Methods

Ten healthy males (21±2y; 182±12cm; 74±10kg) took part in a quasi-experimental trial, during which they underwent a quantitative sensory test of WP and thermal sensation (TS) on hairy (right-side) and shaven (left-side) underarm skin. Participants reported on a 100-mm visual analogue scale the perceived magnitude of WP (0=dry; 100=extremely wet) and TS (0=very cold; 100=neutral; 200=very hot) during repeated contact (5 applications) with a wet cotton patch (0.8ml of water; 1.32 cm^2) secured on a temperature-controlled probe (23°C). Wet stimuli were applied either statically (10s) or dynamically (4x forward-backward motions), alternating between the hairy and shaven underarm. After normality testing, a two-way repeated measures ANOVA was used to examine main effects and interactions between hairiness (hairy vs. shaven) and mode of application (static vs. dynamic) on WP and TS.

Results

There was a statistically significant interaction between hairiness and mode of application on WP (F=6.037, p=0.036, Fig.1A). Post-hoc analyses indicated that a) WP increased from static to dynamic application under hairy conditions only (+19mm; [95%CI 6, 32]; p=0.008) and b) WP were greater between static application under shaven vs. hairy conditions (+18.5mm [95%CI 1.5, 35.5] p=0.036). No differences in WP were observed between dynamic application under hairy vs. shaven conditions (+0.4mm; [95%CI -6.2, 7.0]; p=0.894).

Additionally, there was no statically significant main effect of application (F=2.275, p=0.166), nor hairiness (F=4.167, p=0.072) on TS (Fig.1B); although we note that TS was coldest under static shaven conditions (10mm, 95%CI: -2, 23) and the least cold under static hairy conditions (1.5mm, 95%CI: -14, 17).

Conclusion

The study demonstrated that, the presence of hairs can increase WP during dynamic stimulations, although the resulting WP was not greater than that experienced during static or dynamical stimulation of shaven skin. This novel evidence indicates that under static conditions, hairs could act as thermal insulators and reduce WP; conversely, during dynamic application, hair movement provides mechanical cues that enhance WP to a level equivalent to that experienced with shaven skin. These insights could inform antiperspirant deodorant design that considers users' shaving habits to enhance thermal comfort during application.

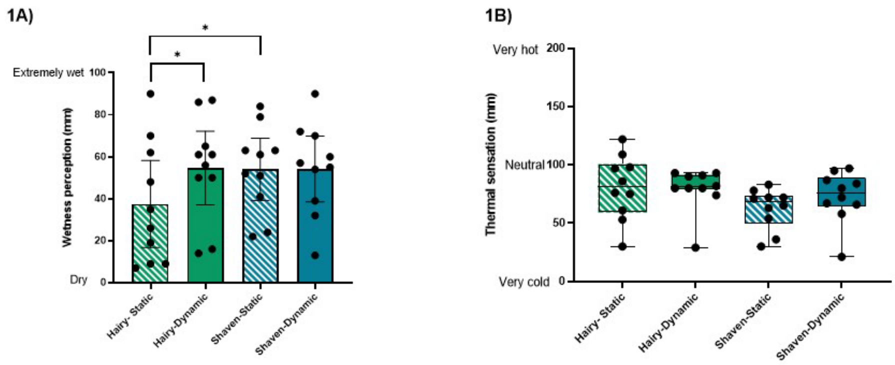

Figure 1. Represents A) wetness perception and B) thermal sensation responses under the two hairiness (hairy and shaven) and application (static and dynamic) conditions. The graphs are presented as mean and 95% confidence interval with individual data points. **Statistical significance $p < 0.005$.*

C29

Hot yoga – A systematic review of the physiological, functional and psychological responses and adaptations

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Background Hot yoga is a collective term used to classify any form of yoga undertaken in warm to hot ambient conditions (≥25°C). This study systematically reviewed the literature concerning hot yoga, with particular focus on acute responses to a single session and identifying prospective health benefits associated with chronic practice across physiological, functional and psychology domains.

Methods The review was conducted in accordance with the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA), with searches performed across two main databases (PubMed and SCOPUS). Studies were included if they met the Population, Intervention, Comparison, and Outcome (PICO) criteria, were of English language, peer-reviewed, full-text original articles, and using human participants.

Results Forty-three studies investigated the effects of hot yoga (both acute and/or chronic), totalling 943 participants (76% female). The most common method of yoga performed in hot conditions was Bikram (76.7%), followed by generalised hot yoga (18.6%), Hatha (7.0%) and then Vinyasa (2.3%). Typical session duration ranged 20–90 min and occurred within 30–52°C and 20–60% relative humidity. Hot yoga training interventions consisted of 6–36 sessions, that were completed 2–6 times per week, over 1–16 weeks. Acute hot yoga increases body temperature and heart rate, but not the energetic demands when compared to other forms of non-heated yoga. Chronic hot yoga appears to elicit cardiometabolic (e.g. body composition, lipid profiles and macrovascular function) and functional adaptations applicable for health (e.g., bone mineral density, balance and flexibility) as well as physical performance (e.g., strength, submaximal exercise thresholds). Such adaptations appear to occur without negatively impacting kidney function, nor sleep quality across healthy, sedentary and athletic populations. Hot yoga presents promising, albeit inconclusive findings concerning the alleviation of psychological and affective disorders, and optimising markers of cognitive function.

Conclusion Investigations into hot yoga demonstrate intriguing health and functional benefits, albeit without mechanistic insights. Claims that hot yoga provides greater health benefits than other forms of yoga are at present, unsubstantiated. Literature describing the benefits of hot yoga are limited in research utilising high-quality experimental designs. Nonetheless, caution is advised when partaking in hot yoga, given various case reports of ill-health. Hot yoga warrants further investigation as a tool to improve health and wellbeing, however researchers should consider the highlighted methodological limitations and recommendations to enhance experimental control within future research.

C30

Wearable Technology – The future of core temperature measurements?

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Introduction: We investigated the accuracy of six non-invasive devices for measuring the body core temperature (Tcore) of people while at rest and during exercise, at cooler and hotter temperatures.

Methods: Thirty participants rested for 30 min in ambient conditions of 25°C / 45% relative humidity (RH) and 60 min at 50°C and 25% RH, followed by a 20-minute bout of cycling at 50°C, at a mean power output of 1.7 W/Kg. Rectal temperature (Trec) was measured throughout, and body core temperature was estimated using three non-invasive wearable devices and three spot-check devices (two aural thermometers and one temporal IR scanner). Bland-Altman plots were used to compare each device with Trec and, alongside root mean square error (RMSE) and intra-class correlations (ICCs), were used to assess device accuracy. Device estimates of Tcore were considered sufficiently accurate if they were within a range of error of ± 0.3°C at each stage of the protocol (the requirement to be certified as a class IIa medical thermometer). The accuracies of all devices were then compared to Tcore estimated from heat storage equations (https://www.nicholasravanelli.ca/hutas/ (Parsons, 2014; Ravanelli et al., 2019)).

Results: The estimates of Tcore from all six devices differed substantially from the rectal thermistor reading (Fig. 1). Only one device demonstrated an acceptable overall agreement with Trec (ICC = 0.790; RMSE = 0.29°C (Table 1)), due to its accuracy at rest (RMSE = 0.27°C). However, the device was inaccurate during exercise and for some participants overestimated by more than 0.5°C, with a RMSE of 0.44°C. All other devices returned an error of over 0.3°C during both rest and exercise. Across devices, mean accuracy was lower during exercise than at rest (RMSE: 0.32 vs. 0.57°C) and the heat storage equations for Tcore were more accurate than five of the six devices, with a RMSE of 0.32°C.

Discussion and Conclusions: The primary finding of this study is that the wearable and spot-check devices did not accurately estimate Trec, particularly during exercise when Tcore was elevated. A predictive heat storage model proved to be more accurate in most cases, which is particularly damning evidence for the efficacy of non-invasive devices. Spot-check devices such as aural and temporal thermometers are routinely used in many acute medical scenarios, but in the present study were less accurate at rest than two of the wearables. Typically, accuracy decreased during exercise, likely due to the rate of change in input variables (skin temperature, heart rate and heat flux) to the device algorithm not correlating with the changes in Tcore. This was further hindered by reduced contact between the devices and the skin from motion and skin wetness.

	CORE	CELSIUM	BODYTRAK	KINETIK AURAL THERMOMETER	BRAUN AURAL THERMOMETER	BOOTS TEMPORAL THERMOMETER	HEAT STORAGE MODEL
NUMBER OF READINGS							
	509	394	162	63	63	63	630
	CORE	**CELSIUM**	**BODYTRAK**	**KINETIK**	**BRAUN**	**BOOTS**	**MODEL**
ICC							
	0.546	0.184	0.790	0.654	0.651	0.007	0.724
	CORE	**CELSIUM**	**BODYTRAK**	**KINETIK**	**BRAUN**	**BOOTS**	**MODEL**
RMSE (°C)							
TEMP	0.43	2.05	0.34	0.71	0.49	0.73	0.28
HOT	0.31	0.71	0.22	0.27	0.43	3.07	0.28
AVERAGE REST	0.36	1.33	0.27	0.42	0.44	2.70	0.28
EXERCISE	0.46	0.68	0.44				0.49
AVERAGE	0.37	1.28	0.29				0.32

Table 1: Core body temperature measurements: Intra-class Correlations (ICC's) and Root Mean Square Error (RMSE) for each device and the heat storage model at rest in temperate (TEMP) and hot environments (HOT) and during exercise, when compared with the reference rectal thermistor.

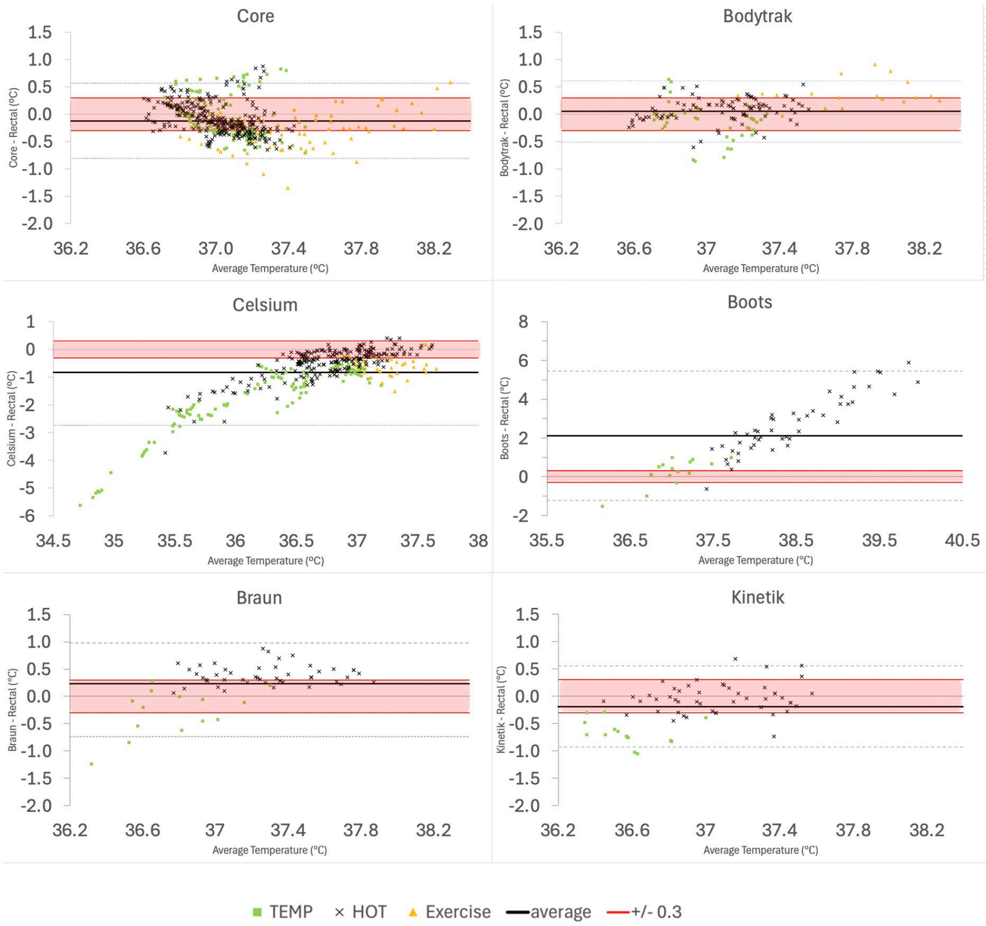

Figure 1: Bland-Altman plots of estimated T_{core} (°C) for the six non-invasive devices compared with the reference rectal thermistor