Shifts in Critical Environmental Limits due to Short- and Medium-term Hot-humid Heat Acclimation

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Introduction

Critical environmental limits, denoted by combinations of ambient temperature and humidity, signify conditions beyond which heat stress becomes no longer compensable for a given metabolic heat production and clothing ensemble. As a result, body core temperatures increase above these limits which enhances the risk of heat-related illnesses. ISO 7243 provides guidelines and upper limits for heat exposure based on the wet-bulb globe temperature (WBGT) separated for acclimatized and non-acclimatized individuals. However, to our knowledge no experimental heat acclimation (HA) intervention study has been performed to assess the effect of HA on critical environmental limits in terms of WBGT ($WBGT_{crit}$). In addition, information on the effect of individual characteristics like body mass or aerobic fitness on HA-induced changes in $WBGT_{crit}$ is lacking. Elucidating the impact of HA and individual characteristics on $WBGT_{crit}$ aids in informed decision making regarding health, safety and performance in warm environments. This study aimed to evaluate the effects of a short- and medium-term HA protocol on $WBGT_{crit}$ and to identify individual characteristics that may predict the effectiveness of HA in enhancing $WBGT_{crit}$.

Methods

Sixteen healthy, unacclimatized females and males performed a maximal graded exercise test to assess aerobic fitness ($VO_{2.max}$) and underwent an assessment of body characteristics (body mass, height, and body surface area-to-mass-ratio). Thereafter they were divided into three groups: a control group and two HA-groups. The control group performed two heat stress tests (HSTs). Both HA-groups executed a HST pre-, during and post-HA. The first HA-group (HA. d5) did a fourth HST following a 5-day decay, while the second HA-group (HA.d10) carried out their fourth HST following a 10-day decay. HA consisted of a hot-humid (35°C, 65% relative humidity) controlled hyperthermia protocol of in total nine days. See Figure 1 for an overview of the study design.

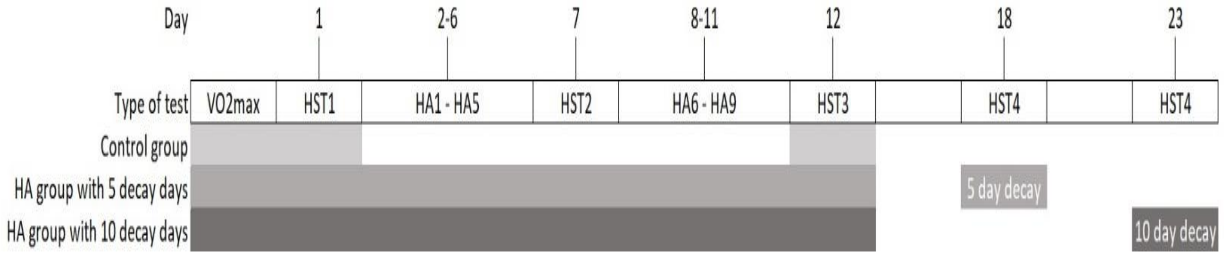

Figure 1. Overview of the study design displaying the measurements executed by the three groups of participants. $VO_{2.max}$ = maximal oxygen uptake. HST = heat stress test. HA = heat acclimation.

Rectal temperature, skin temperature, evaporated sweat rate, whole body sweat rate, heart rate, subjective wellbeing scores and thermal sensation are determined every measurement day. During the HST, participants produce 5 W/kg of metabolic heat on a cycle ergometer for 120 minutes. After a 30-min equilibration period, during which dry-bulb temperature is 38°C and relative humidity 6% are constant, relative humidity is increased with 3%/5 minutes while dry-bulb temperature remains constant. Based on previous research, rectal temperature is expected to stabilize during equilibrium and show a sudden increase during the 90 minutes thereafter, defined as the individual $WBGT_{crit}$ [6].

Results

ISO 7243 predicts a 2°C increase in $WBGT_{crit}$ "for individuals who have been exposed to hot working conditions for at least one full working week", while Bernard et al. [2] argue a 3°C increase is more likely. Vasomotor adaptations are expected within the initial 5 days of HA, sudomotor adaptations typically manifest later [5]. Larger individuals tend to exhibit greater sudomotor adaptation, whereas smaller individuals show a more pronounced vasomotor adaptation. Notably, $VO_{2.max}$ is unlikely to influence the HA adaptation pathway [1]. Consequently, we anticipate considerable interindividual variance in HA-induced changes in $WBGT_{crit}$. Moreover, the anticipated high humidity at $WBGT_{crit}$ during HST may limit the efficacy of sudomotor adaptations.

Taking all into account, we hypothesize our experimental to reveal that:

1. $WBGT_{crit}$ increases approximately 2-3°C as a consequence of HA.
2. 10 days of HA does not further enhance HA-induced $WBGT_{crit}$ changes over 5 days of HA
3. Smaller individuals are projected to experience greater HA-induced WBGTcrit changes compared to larger individuals
4. HA-induced $WBGT_{crit}$ changes are consistent across individuals with different VO_{2max}

Based on a recent meta-analysis, we project a decay rate of -2.5% per day in HA-induced $WBGT_{crit}$ improvements [3].

References

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Practical Implications

This study is poised to offer valuable insights into the dynamics of HA on $WBGT_{crit}$, thereby informing the refinement of guidelines for mitigating heat stress. By elucidating individual variations and the temporal aspects of physiological adaptations to heat, our findings are expected to contribute to more effective strategies for managing heat stress in various occupational and athletic settings.

Preparing for Heat Waves: Heat Acclimation to Enhance Human Thermophysiological Resilience in Overweight Older Adults

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Introduction

As the ongoing progression of climate change increases the risk for more intense and prolonged heat waves, significant concerns raise for public health, particularly among vulnerable populations [1]. Beyond acute measures to protect from heat, such as increased fluid consumption, avoiding direct sun exposure and wearing appropriate clothing, heat acclimation has been proposed as a potential strategy to enhance thermal resilience and mitigate the adverse effects of heat stress [2].

Research has focused on the effects of heat acclimation in athletes and military with protocols using extreme heat temperatures and high intensity exercise [3,4]. Physiological responses induced by active heat acclimation include a decrease in core temperature, earlier sweat onset, increased sweat rate, reduced cardiovascular stress and improved fluid balance. Despite the less intense stimulus, passive heat acclimation has also shown to induce similar physiological effects, although to a lesser extent [5]. To develop a realistic and easy to implement heat acclimation strategy for vulnerable populations, the current study assesses a combination of passive and active heat acclimation to enhance thermophysiological, cardiovascular and metabolic responses to heat exposure in overweight, older individuals. The presented study is currently ongoing, and the first preliminary results will be presented at the conference.

The primary objective of the study is to assess the effect of passive heat acclimation, in combination with low intensity exercise, on thermophysiological and cardiovascular responses in older, overweight individuals. Secondary objective is to assess the effect of passive heat acclimation, in combination with low intensity exercise, on parameters of metabolic health. We hypothesize that 7 days of combined passive and active heat acclimation will enhance human thermal resilience and, therefore, reduce the risk for heat-related illness in older, overweight individuals.

Methods

In a non-randomized, within subject experimental trial, 12 males and females (Age 60-80 y, BMI 25-30 kg/m^2, Sedentary < 2 h of exercise/wk) will undergo one control week (no-intervention) and one week of intervention. The intervention consists of passive heat acclimation (6 h/d, stepwise increase per two days from 29-35ºC, for 7 days) in combination with low-to-moderate intensity exercise (30 min/d cycling, 40% VO2max). Test days will be performed before and after each week to determine physiological responses to increasing ambient temperatures (Figure 1). The test days will consist of a heat stress test (HST; 3 h) and a meal-test (MT; 4h). During the HST, participants will be exposed to gradually increasing temperature reaching up to 45ºC and thermophysiological (core temperature, skin temperature, sweat rate), cardiovascular (heart rate, blood pressure, skin and brain blood flow, flow-mediated dilation), and metabolic (energy expenditure, substrate oxidation) parameters will be measured. During the MT, participants will consume a high-fat mixed drink (11.9 En% protein, 36.4 En% carbohydrates, 53.0% fat) and frequent blood sampling will be done to assess plasma metabolites (glucose, insulin, free fatty acids, triglycerides, total cholesterol).