

From Performance Enhancement to Health: the role of heat acclimation protocols for protecting vulnerable individuals against heat related illness.

Editorial Article

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Sport and exercise science is an academic field encompassing the study of anatomy, physiology, biomechanics, psychology, and nutrition, which aims to enhance performance and health outcomes for athletes and exercisers (Mileva et al., 2022). The adoption of knowledge and practices derived from sport science research in sport, into broader healthcare applications for the general population is not a new concept. Extensive research into concussion management in American football, soccer and rugby has led to improved understanding and treatment of mild traumatic brain injuries in general medicine (Tator, 2013). Similarly, techniques developed for the prevention and rehabilitation of sports injuries such as anterior cruciate ligament injuries have resulted in the advancement of surgical techniques and physical therapy protocols (Mahapatra et al., 2018). Another emerging area of research from sport that may have far reaching implications for public health, is that of heat acclimation protocols.

Heat stress, either as a result of elevated environmental temperatures, endogenous heat production due to exercise, or a combination of the two, leads to increased physiological strain. This increased physiological strain is characterised by increased skin, core and brain temperatures, increased cardiovascular strain, and reduced aerobic performance (Nybo & Rasmussen, 2014; Périard et al., 2011). However, humans are able to adapt to heat stress, with morphological, chemical, functional, and genetic alterations leading to attenuation of these symptoms (Périard et al., 2015). Athletes are routinely expected to participate in activities with high metabolic demands (leading to increased endogenous heat production), and regularly travel from temperate to warm-hot climates for competition (Périard et al., 2015). Where sufficient exposure to natural environments to facilitate acclimatisation is not possible, athletes often choose to utilise acclimation protocols to mimic the thermal stress experienced in hot environments or during high intensity activities.

Heat acclimation (HA) protocols are periods of controlled hyperthermia (core temperature > 38.5°C) designed to elicit beneficial physiological adaptations to enhance performance. When applied correctly, expected outcomes of HA include increased sweat rate and skin blood flow, increased blood volume and improved fluid balance, improved cardiovascular stability, reduced resting and exercising

core temperature, and increased thermal tolerance (Cole et al., 2023; Jackman et al., 2023; Périard et al., 2015). A meta-analysis of 96 studies from Tyler et al. (2016) reported that HA improved time-to-exhaustion and time trial performance by up to ~23% and ~7%, respectively, underscoring the significant ergogenic benefits of acclimation protocols.

There is no single HA protocol appropriate for all athletes and contexts; variations in duration (both in terms of individual sessions and number of days of heat exposure), session arrangement (consecutive versus non-consecutive exposures), temperature, humidity, and activity (active versus passive protocols) have been reported in the literature (Gibson et al., 2020). Customisation of HA protocols should consider factors such as athlete training status, recent environmental exposure, athlete availability and capacity to increase training stress, as well as logistical elements including access to specialist equipment in the absence of a 'natural' environment (Pryor et al., 2019). For athletes living and training in temperate climates, HA is usually achieved with an active, exercise-based protocol, conducted in a heat chamber. The length of the HA protocol will likely influence the level of adaptation achieved, and the rate at which adaptations decay (Pryor et al., 2019). HA occurs relatively rapidly, with some adaptation evident after just a single day of exposure. Short-term strategies are generally considered to be 4-7 days in duration, medium-term strategies are 8-14 days in duration, and long-term strategies are those > 14 days (Cole et al., 2023; Périard et al., 2015). Highly trained athletes adapt well to heat stress during short- or medium-term strategies, whilst continuing to improve their aerobic performance, although it is likely that longer term strategies remain the optimal approach. For less aerobically trained individuals, those competing in multi day events, or in team settings, long-term strategies are likely to be the most efficacious (Pryor et al., 2019).

Just as increased thermal strain can have deleterious effects on exercise performance, it can also negatively impact upon activities of daily living. This is a particularly important consideration for older adults or other individuals who are especially susceptible to heat related illness (Kenney et al., 2014). The world is experiencing a significant change in populations demographics as people live longer, and it is anticipated that by 2050, individuals over the age of 65 will account for approximately 25% of the population (Howdon & Rice, 2018). Although life expectancy is increasing, unfortunately the increase in the average number of 'healthy life years' is not keeping pace (Welsh et al., 2021). This indicates that the number of people vulnerable to heat related illnesses as a result of advancing age and/or pre-existing comorbidities could continue to rise drastically.

Global temperatures are rising as a result of climate change (Calvin et al., 2023), and this is driving an increase in the frequency and intensity of severe adverse climactic phenomena such as heat waves (Calvin et al., 2023). Older individuals are at an increased risk of heat-related illness for myriad reasons,

including limited mobility, co-existing conditions, blunted perceptual responses during exercise, and a reduced ability to regulate internal heat dissipation mechanisms such as the sweat response (Kenney 2014). Available evidence demonstrates that mortality rates in older individuals are increased during heat waves (Arbuthnott & Hajat, 2017), and that there is a direct linear relationship between mortality rates and increases in environmental temperature, where greater increases in mortality are observed during more intense heatwaves (Cheng 2018). The intersectionality of an aging population, and increasing global temperatures therefore poses a considerable public health concern (Khan et al., 2024).

A large body of literature underscoring the link between increased thermal strain and negative health and performance outcomes exists, and has been conducted in both athletic, and non-athletic populations (Arbuthnott & Hajat, 2017; Bell et al., 2024; Cheng et al., 2018). This has also driven research into the role of HA strategies for attenuating decrements in both physical and cognitive markers of performance. However, the majority of this research has been undertaken utilising athletes, or individuals exposed to occupational heat stress such as military personnel and firefighters (Brown et al., 2024). Whilst this offers important insight, and informs practice and policy for these specific groups, there is relatively little data available in relation to older adults or those with additional health considerations (Cole et al., 2023).

Given the concerns regarding the increased frequency and intensity of heatwaves, the related susceptibility of older adults to heat related illness during periods these events, and the potential for HA strategies to increase heat tolerance (Fuji 2021), further research into the use of HA in older adults to protect against heat-related illness is warranted, and necessary (Cole et al., 2023). Currently available evidence from older populations has demonstrated that HA can reduce core temperature (Fujii et al., 2021; Gerrett et al., 2021; Waldock et al., 2021) and/or skin temperature (Best et al., 2014; Waldock et al., 2021) during exercise, increase sweat rates (Armstrong & Kenney, 1993; Best et al., 2014; Fujii et al., 2021; Inoue et al., 1999), and reduce body heat storage (Fujii et al., 2021). All of these physiological adaptations have the potential to offer protection against heat related illness during activities of daily living during periods of high ambient temperatures.

Whilst active HA strategies are commonly implemented by athletes in order to mimic the physiological demands of competition, it is likely not safe or feasible to apply the same protocols in older or vulnerable populations. Those most susceptible to heat related illness may have contraindications to intense exercise, so passive strategies may offer a more feasible approach (Cole et al., 2023). Passive strategies can confer many of the same physiological adaptations as exercise-based interventions, leading to improvements in a number of markers that can positively impact upon cardiovascular

health and heat tolerance (Cole et al., 2023; Pallubinsky et al., 2017). This would be of significant benefit to older or vulnerable individuals, and may prevent against, or reduce the severity of, heat related illness in extreme climactic conditions such as heat waves (Kenney et al., 2014).

Passive HA strategies rely on external heat exposure, rather than endogenous heat production, to increase core temperature above 38.5°C to initiate adaptive responses. As such, these approaches are more appropriate for individuals unable, or disinclined, to exercise. Whilst environmental chambers capable of mimicking hot-dry or hot-humid environments are commonplace in elite sport settings, they are not generally accessible to the wider public. Alternative options such as hot water immersion, or the use of heated garments or saunas may offer more accessible and lower cost options that could be implemented without the need for such specialised facilities.

Passive HWI, which involves immersing the whole body into water heated to ~40°C for 40 minutes or longer, has been shown to elicit comparable adaptations (including reduced peak and average heart rates, average core temperature, rating of perceived exertion and peak thermal sensation during a heat stress test compared to pre-intervention) to a time-matched exercise heat acclimation protocol in non-acclimatised healthy adult males (Greenfield et al., 2021). A more recent study from Deshayes et al. (2024) reported that following 7 consecutive days of HWI at 40°C, core temperature decreased and sweat rate increased in older adults. These adaptations reduced the mean body temperature onset threshold for both local sweat rate and cutaneous vascular conductance during a subsequent heat stress test compared to baseline values. The authors noted that the increase in whole body sweat rate was slightly blunted in the older adults (66 ± 5 years) compared to younger healthy comparisons (27 ± 5 years), but no other markers of human heat acclimation. These findings further support the notion that passive HA strategies can reduce feelings of fatigue and physiological strain during tasks of daily living, and that together these adaptations may protect vulnerable individuals against heat related illness during periods of high ambient temperatures.

In order to identify optimal and efficacious passive HA strategies that can be implemented in advance of severe weather conditions, much more research is required. Future studies in this area should focus on the following; i) identifying the most effective and accessible methods of applying HA for vulnerable populations, ii) the minimum dose required for adaptation; either in terms of number of days, or number of exposures, and iii) understanding the rate of decay of adaptive responses in this population. Increasing knowledge in these areas would allow for the formulation of best practice guidelines and protocols in an effort to protect vulnerable individuals against intolerable heat stress during heatwaves.

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