Knowledge and Practices of Heat Acclimation in Recreational Runners

By

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ABSTRACT

Heat acclimation is the foremost method of preventing exertional heat illness during exercise in hot and humid environments. However, the prevalence of heat acclimation (HA) training and associated knowledge is not currently known in recreational running populations. The purpose of this dissertation was to determine the knowledge and practices of recreational runners toward HA across two studies. Additionally, participants' training practices were examined for signs of natural HA as well as differences in knowledge and practice among participants of different training status.

In study one, recreational runners in the Southeastern United States (N = 125) demonstrated a lack of knowledge toward proper HA training and associated benefits. Participants largely received HA advice from their peers (31.2 %) and a large majority reported no professional guidance in their training (79.2 %). Finally, participants' beliefs toward proper HA training differed among training groups with moderate and high groups perceiving greater frequency, miles/wk, and min/wk as appropriate for HA compared to the low group ($p \leq .05$).

In study two, it was determined that participants' HA practices did not meet the current recommended professional guidelines regardless of training status. Participants preferred running for HA purposes (88.8%) with the majority preferring to run before 8 am (41.6 %). A total of 85.6% of participants reported their performance had suffered due to overheating with no association found by training group (N = 125; χ^2 = 2.10; p = .35). Yearly occurrence of exertional heat illness (EHI) symptoms was not statistically

different among participants of different training status, however there was a trend for participants in the low group to experience less nausea ($M_{\text{difference}}$ = -1.65; d = -0.41) and muscle cramps ($M_{\text{difference}}$ = -0.90; d = -0.31) compared to the high group. Finally, while there were statistically significant differences in some participants' duration, miles/wk, or min/wk of exercise across seasons ($p \leq .05$), a general consistency in training variables throughout a training year was present. In conclusion, governing bodies in exercise and sports should consider developing more comprehensive and more widely distributed educational initiatives for the recreational running population regarding HA and EHI prevention.

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CHAPTER I

Extreme heat stress is a concern especially in the Southeastern United States where rates of heat illness tend to be higher (Harduar-Morano et al., 2015). Many high-level athletes have the luxury of training under knowledgeable professionals who are aware of the signs, symptoms, and treatment strategies of heat illness (Mazerolle et al., 2010). These professionals ultimately serve as a valuable resource in improving performance and in helping reduce the risk of injury during training for the competing athlete who performs in thermally stressful conditions. However, one population that does not have this resource is recreational runners, which in addition, have been shown to have limited knowledge on the increased risk of heat illness in hot, humid environments (tmep, RH; Hosokawa et al., 2019).

Heat acclimatization (HA) is the foremost method to enhance performance and mitigate the chance of heat illness during exercise (Racinais et al., 2015). Several methods to attain HA all result in physiological adaptations but differ in their approach. Traditional recommendations to attain heat acclimatization (HA) often involve exercising at a relative intensity of $\geq$ 50%VO_{2max} for 60 minutes per day, over 1-2 weeks, while gradually increasing the workload and exercise duration (Racinais et al., 2015; Wendt et al., 2007). The second method, often called "controlled hyperthermia" involves maintaining an elevated core temperature at a specific value by constantly adjusting the exercise work rate. The final method is known as the “controlled work rate model” which involves maintaining a constant work rate throughout the exercise session, allowing for a continual rise in core temperature (Tyler et al., 2016).

The process of HA results in specific physiological changes such as reduction in exercising core and skin temperatures, expansion of plasma volume, and greater sweat rates, in order to assist the human body in dissipating heat (Périard et al., 2015). Evidence toward the efficacy of HA is numerous in the literature and is used by professional athletes to elicit a performance advantage during athletic events (Périard et al., 2017). However, very few data are available to gauge the knowledge of recreational runners regarding HA. Furthermore, there are currently no studies that have attempted to assess specific HA practices in recreational runners.

Overall Purpose

To combat the occurrence of exertional heat illness (EHI), it is critical for recreational athletes to be aware of the various methods that are available to protect themselves while simultaneously enhancing exercise performance. Due to the lack of data available on the practices and knowledge of HA in this population, it is difficult to determine if there is a need to develop more educational materials for the recreational athlete involved in distance running. The purposes of this dissertation are to assess the knowledge of proper HA techniques in the recreational running population of the Southeastern United States, determine the training habits of the recreational running population throughout the year for signs of natural HA, and compare HA knowledge and practices between recreational runners of different training statuses.

Significance of Studies

This survey could serve to benefit not only recreational runners, but also governing bodies in exercise and sports by helping them determine if new educational initiatives need to be created. This could aid in the development of new ways to disseminate information to the recreational athlete who regularly participates in moderate to high intensity running in thermally stressful environments. Ultimately, the population in question would be more knowledgeable in the various strategies that serve to reduce heat illness and improve exercise performance in the heat.

CHAPTER II

REVIEW OF LITERATURE

This literature review will discuss the underlying mechanisms involved with heat acclimation and acclimatization that aid in the prevention of heat illness and enhanced performance. While both acclimation and acclimatization both induce virtually the same physiological changes, the former refers to heat adaptation in an artificially controlled environment and the latter involves adaptation in the natural environment (Périard et al., 2015). For the purposes of this review, both terms will be referred to as HA. The review will start by presenting the dangers, symptoms, and outcomes of EHI. Second, the physiological and perceptual adaptations and the underlying mechanisms involved with HA will be examined along with how these adaptations benefit health and exercise performance. Methodology and findings of past studies will be examined, critiqued, and summarized while areas that currently lack clear understanding will be noted. Finally, current information in the literature regarding the limited understanding of HA knowledge and practices across the recreationally active population will be addressed. The literature review will end with a proposal for gathering more data to determine HA knowledge and habits in recreational athletes via two surveys in order to establish whether this population needs further education in the realm of heat stress mitigation via HA.

Dangers of EHI

Exertional heat illness (EHI) is an all-encompassing term for a variety of conditions characterized by an elevated core temperature. Specifically, a core temperature of > 40° C with extremely wet and pale skin, is considered Heat Stroke. An elevated core temperature < 40° C with symptoms such as headache, nausea, and vomiting are considered Heat Exhaustion. Along with EHI, other conditions may also manifest simultaneously due to excessive heat strain such as rhabdomyolysis and hyponatremia.

Rhabdomyolysis is defined as the dissolution of skeletal muscle components into the bloodstream, often caused by intense exercise and hyperthermia. The prognosis of this condition often includes acute kidney injury or organ failure if treatment is not administered quickly (Torres et al., 2015). Hyponatremia is defined as dangerously low plasma sodium concentrations that lead to cell swelling. Prior to or during exercise, hyponatremia often occurs due to over consumption of water, heat stress related cell damage, and excess sodium loss in sweat (Adrogué & Madias, 2000; Armstrong et al., 2007). If not treated quickly, this condition can result in significant brain damage or death. To reduce the risk of developing these conditions while exercising in the heat, HA knowledge and practices are advised to elicit specific physiological changes to help mitigate increases in body temperature and maintain fluid balance.

Cardiovascular and Hormonal Adaptations

Cardiovascular adaptations are a key feature of HA and some of the first to manifest after repeated exposure to thermal stress (Périard et al., 2016). The pathway in which these adaptations occur are related to changes in fluid conservation at the kidneys via increased hormone production (Garrett et al., 2011; Racinais et al., 2019). This leads to a better plasma and sodium balance which helps prevent blood pooling and sweat cessation (Donaldson et al., 2003). The following sub sections will highlight key physiological adaptations of the cardiovascular system as a result of HA and how these adaptations assist in maintenance of proper cardiac function and exercise performance in the heat.

Hormones, Sweating, and Electrolytes

Sweat production at a higher rate allows for more skin surface area to be covered in sweat, leading to more potential cooling of cutaneous circulation via evaporation, thus blunting increases in core temperature (Buono et al., 2009; Collins et al., 1966; Fox et al., 1964). Early studies in the 1960's introduced this concept by HA participants' whole bodies or specific surface areas. Fox et al. (1964) subjected 12 U.S. Army service men to 15 days of HA with additional heating of one arm. Pre to post HA and hot bath comparison demonstrated that participants who underwent both HA and bath treatment experienced increased sweat losses in the treated arm compared to the control arm. More recent data has also agreed with this finding. Buono et al. (2009) subjected 8 physically active participants to 0.1 ml injections of Botox into the forearms to inhibit sweating, or a saline solution to serve as a control. After injection, a 10-day HA protocol was conducted, and participants' sweat rates were measured pre and post treatment. Results of the experiment demonstrated an 18% increase in sweat rate of the control arm and a 52% reduction in the BOTOX treated arm, suggesting a heat stimulus related sweat gland adaptation to repeated heat exposure.

In addition to producing higher volumes of sweat at an increased rate, eccrine glands also secrete less NaCl after HA (Allen & Wilson, 1971; Chinevere et al., 2008;

Kirby & Convertino, 1986). This phenomenon is due to increased Aldosterone concentrations that influence Na-K-ATPase activity (Baker, 2019; Nielsen et al., 1993; Sato & Dobson, 1970). Past experiments have shown increased Aldosterone concentrations in participants post HA (Armstrong et al., 1989; Nielsen et al., 1993) suggesting a hormonal influence on sweat gland activity leading to Na^+ reabsorption at the sweat glands which allows for better plasma osmolality. Na-K-ATPase is an enzyme responsible for stimulating channels that line the sweat duct. As hypertonic solution passes through the duct then Na-K-ATPase stimulates the opening of the specific channels to allow reabsorption of Na^+, Cl^-, and K^+. More Aldosterone is likely to elicit greater Na-K-ATPase activity which in turn helps maintain plasma osmolality and may help prevent hyponatremia. These adaptations ultimately lead to a cascade of hormonal reactions that assist in maintaining cardiac output (Q).

Plasma Volume, Stroke Volume, and Cardiac Output

With increased NaCl reabsorption, the osmolality of blood plasma increases. To maintain a proper Na^+ concentration, the hormone Vasopressin is released from the posterior pituitary gland and stimulates reabsorption of water by way of the collecting tubules of the kidneys (Hew-Butler, 2010). Increases in Vasopressin and Aldosterone mediated water reabsorption lead to enhanced plasma volume (PV), which is beneficial in maintaining cardiac output (Q) during exercise in thermally stressful conditions (Garrett et al., 2011; Racinais et al., 2019). In addition, the amount of Albumin protein is enhanced post exercise in the heat serving to increase oncotic pressure and causing a movement of fluid to the circulation from interstitial spaces (Gillen et al., 1991). The resultant greater PV is thought to lead to a greater stroke volume (SV) via enhanced preload.

Despite the amount of evidence in favor of the large influence that increased SV has on Q, recent data has challenged this notion. Travers et al. (2020a; 2020b) examined eight trained endurance athletes pre- and post-10-days of HA (40°C, 40% relative humidity) with Q and SV being measured indirectly via the product of HR and SV and echocardiogram respectively. during exercise and rest. Results of the study indicated a 5% increase in Q and a significant slight 9 mL increase in SV. What is most interesting about the results of this study however is that no changes in end diastolic volume were witnessed. This led the authors to conclude that increases in PV may not be the most important factor dictating increases in Q after HA. In their review, Périard et al. (2016) highlight the numerous variables that influence regulation of autonomic activity of the heart such as altered baroreflex and chemoreflex activity. Finally, it is important to note that both end diastolic volume and PV were not directly measured in Travers et al. (2020a;2020b) and were derived from total blood volume and red cell volume and thus the results should be met with caution.

Although HA mediated increases in Q due to expansions in PV and SV (Goto et al., 2010; Lorenzo et al., 2010; Nielsen et al., 1993) are commonly reported, opposing results do exist (Keiser et al., 2015; Nielsen et al., 1997; Sotiridis et al., 2019). It has been proposed that this discrepancy may be due to differences in the type of heat stress (hot, dry vs. hot, humid) implemented during the HA protocols or training intensity utilized in the protocols (Periard et al., 2015). While it is possible that the type of heat stress is responsible for these conflicting results, that conclusion is difficult to make based on the limited number of HA studies that have involved high humidity environments. A meta-analysis conducted by Tyler et al. (2016) identified 96 HA studies for assessment, with 78 reporting the relative humidity (RH) utilized in the experimental procedures. Out of the 78 studies that reported RH, only 33.3% involved environments with RH's ≥ 50%. Additionally, a follow up meta-analysis by Rahimi et al. (2019) assessing only level 1 randomized controlled trials identified 11 eligible HA studies. Out of the 11 studies, 5 (~45%) acclimatized participants in environments containing RH's of ≥ 50%. Thus, it appears that more studies should attempt to examine the effects of high vs low RH on HA adaptations.

Finally, it possible that inter-individual variability to HA protocols may explain some of the discrepancies found in the literature. Corbett et al. (2018) attempted to determine mechanisms behind inter-individual variability to HA adaptations in trained males. Seventeen participants underwent HA over 11 days in a hot, humid environment (40°C, 50% RH) after which a series of HA adaptations including T_{rec}, whole body sweat rate, and blood volume were analyzed for correlation with VO2max, prior HA experience, and amount of thermal stress experienced during the HA protocol. Results of this study saw a wide range of responses toward HA, leading the authors to categorize the participants as "low" or "high" responders. However, results of the Pearson's correlation revealed no significant relationships between magnitude of HA adaptations and absolute or relative VO_{2max}. The authors concluded that perhaps genetic factors play a role in an individual's response to HA, however there are currently no studies examining such factors to the knowledge of the current author.

Heart Rate

With an increase in SV and greater ventricular filling, resting and submaximal exercising heart rates (HR) have been shown to decrease after HA (Garret et al., 2011; James et al., 2018; Lorenzo et al., 2010; Nielsen et al. 1993;). Reductions in norepinephrine have also been recorded after HA, suggesting an additional hormonal influence on HR (Febbraio et al., 1994; Hodge et al., 2013; Stacey et al., 2018). Since exercise in the heat is known to lead to excess stress on the cardiovascular system via dehydration (Travers et al., 2020a; Travers et al., 2020b), proper hydration practices pre and during exercise, as well as increases in PV and SV from HA decrease the risk of cardiovascular drift.

Maximal Oxygen Consumption and Performance

Increases in blood volume likely increase performance as well. The recent meta-analysis by Tyler et al. (2016) notes a moderate to large endurance performance enhancement from HA protocols. Whether the improvement is due to changes in oxygen uptake or circulatory related adaptations are equivocal and continue to be controversial. Some studies have witnessed improvements in VO_{2max} after HA across a range of thermally diverse environments (James et al., 2018; Lorenzo et al., 2010; Sawka et al., 1985). Others have witnessed improvements only in thermally stressful conditions (Karlson et al., 2015; Keiser et al., 2015; Waldron et al., 2019) or little to no improvements at all (Chen et al., 2013; Fry, 2020; Kirby & Convertino, 1986; Mikkelson et al., 2019; Neal et al., 2016; Sotiridas et al., 2019; Travers et al., 2020b).

In their editorial commentary, Nybo and Lundby (2016) proposed that prevalence of such mixed responses across studies may be due to a lack of control groups, citing the results of their recent studies. In their counterbalanced, crossover design, 8 endurance trained males were assessed on a variety of performance variables in hot and cool conditions after HA. Results of this study showed improvements in VO_{2max} and Time Trial performance post HA in hot conditions, but no changes were evident in cool conditions (Keiser et al.,2015). Several others have also seen agreeable results. Karlsen et al. and Racinais et al. (2015) implored similar methodology except for including separate control and experimental groups. The results of this study indicated no crossover effect of HA to cool environments, although Time Trial performance in the heat was improved after HA. Finally, more recent studies by Mikkelson et al. (2019) and Olberholzer et al. (2019) saw no changes in VO_{2max} and similar improvements in Time Trial performance between experimental and control groups. Although it is likely that HA does indeed increase VO_{2max} in hot and humid environments, sufficient amounts of evidence are currently lacking to determine an environmental crossover to thermoneutral or cold environments.

Factors that Effect Thermoregulatory Adaptations to HA

Upon the initiation of exercise, thermal receptors in the skin and spinal cord sense thermal input and the concomitant rise in circulating blood temperature, providing feedback to the anterior hypothalamus. Together with the warm blood perfusing the hypothalamus, a stimulus is provided to initiate thermoregulatory responses throughout the body (Powers & Howley, 2018). This response serves as the main avenue for heat transfer to the skin via increased vasodilation and peripheral blood flow, and eventual transfer of heat to the external environment via evaporation of secreted sweat (Wendt et al., 2007).

Heat acclimation helps mitigate heat stress by increasing the core to skin and skin to environment temperature gradients. Thus, individuals who have undergone HA have been shown to exhibit lower resting and exercising core temperatures (T_c; Garden et., 1965; James et al., 2017; Karlsen et al., 2015; Nielsen et al., 1997). Lower resting skin temperatures (T_{sk}) are not typically seen in the literature (Tyler et al., 2016). However lower exercising T_{sk} values are commonly reported (Lorenzo et al., 2010; Nielsen et al., 1993; Rendell et al., 2017; Travers et al., 2020b). With larger T_c to T_{sk} to environment temperature gradients, the ability to perform prolonged physical activity in hot, humid environments is extended before a critical T_c (40°C) is reached as evidenced by numerous studies showing greater time to exhaustion or slower rises in T_c (Chen et al., 2013; Garden et al., 1965; Hodge et al., 2013; Mikkelson et al., 2019; Nielsen et al., 1997).

Effect of Age

As humans age, notable physiological changes occur that lead to impaired heat dissipation (Balmain et al., 2018). Some of these impairments include decreased sweat rate, evaporative heat loss, and skin blood flow (Kenny, 2017; Larose, 2013; Tankersley et al., 1991). The combination of these age-induced decrements hinder thermoregulation making heat dissipation in hot or humid environments especially difficult for the elderly (Donaldson et al., 2003; Larose et al., 2014; Westaway et al., 2015). However, it is important to note that older individuals have been found to benefit from HA via many of the same adaptations as their younger counterparts, even across a wide range of fitness levels and when utilizing varying exercise intensities (Best et al., 2014; Inoue et al., 1999). Inoue et al. (1999) examined physiological responses to HA in sedentary younger and older men vs. highly fit older men at a low exercise intensity (35% VO_{2max} for 90 minutes) in a hot, dry environment (43°C, 30% RH). Older men underwent similar HA adaptations as the younger counterparts such as decreased T_{rec} and sweat Na^+ concentrations. Additionally, highly fit older men experienced similar sweat rates as sedentary younger men and higher sweat rates than sedentary older men, promoting the importance of thermoregulatory adaptations from regular physical activity engaged in a moderately challenging environment.

Some have suggested HA be avoided in elderly populations due to diminished thermoregulatory responses (Millyard et al., 2020) and its subsequent effect of preventing protocol adherence as seen in Daanen and Herweijer (2015). However, examination of this study's methodology explains the author's interpretation. The HA protocol used by Daanen and Herweijer (2015) consisted of only 3 days of heat exposure. Adaptations to the heat are known to manifest typically after a minimum of 4 days (Periard et al., 2016). The participants recruited were also sedentary and > 75 years old, therefore it is not surprising that the workload had to be reduced for participants to complete the HA protocol. It is the view of the current author that HA in elderly populations can serve as a valuable tool in reducing exercise heat stress. Protocols in these populations likely need to include lower exercise intensities and proper hydration practices to reduce the chance of dehydration related heat illness and cardiovascular stress. Finally, greater precaution should be taken if HA is to be undertaken in hot, humid environments due to lower levels of evaporative heat loss found in older populations (Larose et al., 2013; Larose et al., 2014).

Adolescents exercising in the heat often experience inferior thermoregulation versus adults due to underdeveloped sweat glands and reduced mechanical efficiency

(Notley et al., 2020). Studies examining physiological adaptations to HA in children are sparse. With the available data, it appears that children undergo at least some of the HA adaptations seen in adults, namely, reductions in HR, T_c, and T_{sk} (Dougherty et al., 2009; Inbar et al., 1981; Inbar et al., 1985). Due to the lack of available data, it is recommended more studies be conducted to examine the effects of HA in children.

Effect of Sex

Although females are known to dissipate heat as well as men, unique physical and physiological differences exist that affect the sexes in separate ways. Females have been shown to have lower sweat rates and cholinergic sensitivity while males tend to produce more sweat and rely more on evaporative heat loss due to a greater body mass and surface area, and total metabolic processes occurring (Baker, 2019; Gagnon & Kenney, 2012). In addition, physiological factors such as menstrual cycle mediated changes in peripheral blood flow, vascular resistance, core temperature, and hormone production also exist (Bartelink et al., 1990; Gagnon & Kenney, 2012; Yanovich et al., 2020). When considering the mechanism of evaporative cooling, less transfer of heat from the core to the periphery appears to be a disadvantage. Together with a menstrual cycle related increase in core temperature, it could be extrapolated that females have a less effective thermoregulatory system. However, this only appears to be the case in hot, dry environments as females experience lower T_c and T_{sk} compared to males in hot, humid environments, allowing for greater radiative, convective, and conductive heat loss (Shapiro et al., 1980).

The current literature demonstrates similar HA adaptations between males and females aside from depressed sweating adaptations in the latter (Avellini et al..1980;

Weinman et al., 1967; Yanovich et al., 2020). Though, more recent evidence has identified a possible timeline to elicit full heat adaptation in females. Subpar HA adaptations when females were acclimatized over short (4-5 days) vs. long duration protocols (9-10 days) have been documented in several studies (Kirby et al., 2019; Mee et al., 2015). Even though the current data are limited in capacity, the current author suggests female athletes be provided an adequate time of at least 10 days to allow full manifestation of thermoregulatory adaptations.

Factors that Effect Skeletal Muscle Adaptations to HA

The effects of HA on skeletal muscle characteristics and fitness parameters are currently unclear due to a lack of studies. The limited data that are currently available suggest that traditional HA protocols (5-10 day durations) increase mean and peak power during sprinting (Brade et al, 2013; Castle et al., 2011;; Garrett et al., 2019; Wingfield et al., 2016). More recent studies have demonstrated greater muscular fitness adaptations with added heat stress, but the statistical techniques implored are questionable as the authors used Magnitude Based Inferences to determine significance (Casadio et al., 2017; Miles et al., 2019). Although popular in recent years within sport and exercise related academic journals, the technique is known to provide a high risk of Type I errors and has been banned by the flagship journal of the American College of Sports Medicine (Gladden, 2019; Lohse et al., 2020; Sainani, 2018).

Skeletal Muscle Adaptations and Performance

To the knowledge of the current author, only one study to date has examined the effects of HA on muscular strength. Miles et al. (2019) exposed professional male rugby players to a 3-week resistance training program in hot, dry (35°C, 37% RH) or thermoneutral conditions (21°C, 45% RH). Post intervention testing indicated that the HA group had a greater increase in muscular strength on the bench press (5 kg vs. 1 kg) and the squat (9 kg vs. 3 kg) compared to the thermoneutral group. The discrepancy between the groups may be related to changes in lean mass as the HA group increased total body mass by 1.5 kg while the control group saw reductions in body mass by 0.8 kg. A possible reason for this finding may be due to increased anabolic hormone release post exercise as a resistance training session in the heat has shown to elicit a greater hormone response (Casadio et al., 2017). Additionally, no measures of body composition or sweat losses were reported, further confounding the author's interpretation of the results.

Despite the observations made by Casadio et al. (2017), others have found decreased levels of testosterone and Interleukin-6 and increased levels of Cortisol after resistance training in the heat (Eskandari et al., 2020). A key difference in the study by Eskandari et al. (2020) is that participants were untrained as opposed to the professional athletes studied in past experiments (Miles et al., 2019). Additionally, Eskandari et al. (2020) recognized that serum hormone measurements were made shortly after the resistance training session and measurements later in the recovery period may have displayed different trends. Finally, it is worthy to note that readers should practice caution when interpreting the statistical meaningfulness of Miles et al. (2019) and Casadio et al. (2017) as both utilized a Magnitude Based Inference approach when analyzing the data. Statistical procedure aside, the current author argues the practical meaningfulness of a HA training protocol that elicits up to a 6 kg strength advantage and 85-107% increase in growth hormone witnessed in these two studies, compared to not undertaking an HA protocol.

In addition to more traditional HA methods, some have examined the effects of repeated passive heat exposure on skeletal muscle, demonstrating greater peak torque, rate of torque development, and cross-sectional area between treated and untreated quadriceps (Goto et al., 2010; Kim et al., 2020). Still, there are contrasting results showing no apparent advantage of passive heat exposure with resistance training over 12 weeks compared to resistance training alone in a more recent study (Stadnyk et al., 2018). With so few data available for passive heat exposure and its effects on skeletal muscle, it is difficult to determine the efficacy of this technique on skeletal muscle adaptations and performance. To this end, there is currently a need for studies examining the effects of both traditional and non-traditional HA protocols on muscular fitness characteristics and performance adaptations.

Factors that Effect Perceptual Responses to HA

Data regarding the effect of HA on perceptual responses is scarce, a recent meta-analysis identifying only 5 studies measuring rating of perceived exertion (RPE) and thermal comfort (TC) (Rahimi et al., 2019). Examination of the currently available data demonstrates that reductions in RPE, TC, and thermal sensation (THS) may be attained from HA (Neal et al., 2016; Willmott et al., 2017; Willmott et al., 2018; Willmott et al., 2020). However, an almost equal number of studies show no changes in perceptual responses after HA also exist (Garrett et al., 2011; Lorenzo et al., 2010; Magalhães et al., 2010). Possible reasons for the discrepancies between these studies include a wide range of ambient temperatures and relative humidity's utilized (35-45°C; 20-60% RH), differences in thermal sensitivity of specific skin surfaces, and aerobic fitness status of participants, which are all known to influence perceptual responses to thermal stimuli (Cheung, 2010)

Performance

Reductions in TC, THS, and RPE may well relate to improved exercise performance via better pacing (Cheung, 2010). Although, past studies demonstrating the influence of skin temperature as a regulator of self-selected exercise intensity are mixed (Levels et al. 2012; Schlader et al. 2011;). As highlighted by Cheung (2010), one of the more prominent hypotheses explaining the effect of perceptual responses on performance is that of Tucker (2009) and the "Anticipatory Feedback Model". This model suggests that maximum RPE is predetermined at the start of exercise based on physiological or environmental feedback. In this model, afferent feedback on the amount of stored glycogen or ambient conditions for example, is sent to the brain whereby a maximum RPE is pre-determined thus limiting exercise intensity.

Applying this model to the current review on HA and exercise in the heat, afferent feedback from the internal and external environmental conditions would serve to provide an anticipated heat stress load. This would result in a predetermined maximum perceptual response value being set and adjusted as exercise commences in order to prevent a dangerous core temperature (T_c). Since HA results in greater temperature gradients between the body and environment, the lowered T_c and skin temperature (T_{sk}) values from HA would serve to provide feedback toward a lower anticipated heat stress. Thus, the predetermined perceptual responses would be set at lower values, resulting in better thermal comfort and RPE during exercise.

Effect of Sex

When considering HA related improvements in perceptual responses, it can be argued that females may receive more of a benefit versus their male counterparts. Females are more thermally sensitive to heat-based stimuli and initiate behavioral thermoregulatory actions earlier (e.g., applying a cooling stimulus) than men (Garrett et al., 2014; Inoue et al., 2016; Schweiker et al., 2018; Vargas et al., 2019). Thus, a reduction in TC and TS may result in better exercise performance. Parton et al. (2021) recently demonstrated that females also alter pacing during aerobic exercise after decreases in TS. In this study, twenty-two (11 males, 11 females) participants completed cycling exercise under hot conditions (34.9°C, 40.6% RH) to examine the effects of L-menthol exposure on perceptual responses and performance. Although L-menthol lowered TS for both sexes, only males increased their cycling pace as a result. The authors of this study suggested that due to a lack of change in cycling pace, females may be able to extend time to exhaustion. This factor would be useful in long duration events but may also serve as a disadvantage in females for races that are moderate in length where speed is a more important factor. In contrast, males may benefit more from altering TS in events that are shorter in duration.

Effect of Age

Aging negatively affects perception of thermal stimuli as manifested through decreased thermal sensitivity (Inoue et al., 2016; Takeda et al., 2016). The reasons for this phenomenon are multifactorial but are largely accounted for by age related changes in skin such as reduced nerve density, decreased vascular conductance, and reduced sweating capacity (Guergova & Dufour, 2011; Millyard et al., 2020; Shibasaki et al., 2013). Some evidence suggests that HA assists with TC in elderly populations. Inoue et al. (1999) examined physiological and TC differences between young and older men pre and post 8 days of HA and found similar improvements in both age groups. In addition to TC, HA may also improve age related declines in thirst drive which would be beneficial in preventing dehydration (Takamata et al., 1999). While the current data is in favor of beneficial physiological adaptations from HA, more studies are currently needed to assess the efficacy of HA on perceptual responses in the elderly.

Metabolic Responses

Intense aerobic exercise in hot or humid conditions increases the body's reliance on glucose as a fuel source which leads to greater lactate production (Hargreaves et al., 1996; Starkie et al., 1999). A greater rate of carbohydrate oxidation may then increase the risk of glycogen depletion and impair performance. Another key adaption from heat acclimation is carbohydrate sparing via greater free fatty acid utilization (Kirwan et al., 1987). The following subsections will highlight key physiological mechanisms that increase carbohydrate oxidation in the heat and how this is mitigated by HA induced adaptations.

Carbohydrates, Fats, Lactate

Heat stress has been shown to lead to elevated epinephrine and norepinephrine during exercise, leading to an increase in carbohydrate oxidation and lactate accumulation (Hargreaves et al., 1996; Parkin et al., 1999). The mechanism behind the hormone increases in carbohydrate oxidation and lactate production are related to increased glycogenolysis and pyruvate dehydrogenase activity (Watt et al., 2001). Heat acclimatization has been shown to reduce epinephrine concentrations similar to values witnessed in thermoneutral environments, thus reducing the stimulus that increases carbohydrate oxidation and resulting in less lactate formation. Heat acclimatization also assists in mitigating lactate accumulation by enhancing cardiac output, allowing for better distribution of blood flow between the skeletal muscles and periphery (Periard et al., 2015).

Although limited in number, past studies have reported a glycogen sparing effect of HA along with decreased lactate production (Febbraio et al., 1994; King et al., 1985). This phenomenon is likely due to increased fat oxidation by the skeletal muscles. Kirwan et al. (1987) examined the effects of HA on substrate utilization in physically active college aged males after 8 days of HA in a hot, dry environment (39.6C, 29.2 % RH) and witnessed greater fat oxidation (+5.74 g/hr), with a reduction in carbohydrate oxidation (-10.35g/hr). The reasons for the glycogen sparing witnessed in these studies is multifaceted although it is likely that the combination of greater skeletal muscle blood flow and reduced catecholamine concentrations from HA lead to greater fatty acid transportation and availability (Febrraio et al., 1994; King et al., 1985).

Heat Acclimation Knowledge and Practices in Recreational Athletes

Relatively little is known about HA practices in recreational populations. To the knowledge of the current author, there are currently no studies that have attempted to survey this demographic to determine their knowledge or practices regarding the specifics of HA. Hosokawa et al. (2019) surveyed 2091 recreational runners prior to a racing event and found that only 47.4% were able to identify the correct number of days for a HA protocol. In addition, others have found that large portions of the recreationally active population have a limited understanding of the dangers involved with Exertional

Heat Stroke (EHS). Shendell et al. (2010) surveyed recreational marathon runners competing in the Southeastern United States and found that 47.9% did not understand the risk of death involved with EHS.

Additionally, recreational athletes often train in dehydrated states (Bigg et al., 2019; Peacock et al., 2011), increasing the chance of Exertional Heat Illness (EHI). O'Neal et al. (2011) surveyed recreational runners prior to a marathon in the Southeastern United States and found that 23% of runners had experienced symptoms of EHI. Furthermore, 64% reported receiving hydration advice from their peers. In relation to HA, it is possible that recreational athletes also receive HA advice from their peers or may even have a lack of knowledge regarding HA. Heat acclimation is the foremost strategy recommended by the National Athletic Training Association to combat the occurrence of EHI in athletes (Casa et al., 2012). Thus, education and awareness of proper HA strategies that can be implemented is of upmost importance for the health and safety of athletes performing in thermally stressful environments.

Conclusion

Heat acclimation elicits a host of beneficial adaptations that assist in temperature regulation and help reduce the occurrence of EHI. Although common among professional athletes, it is not currently known the occurrence at which recreational athletes consciously or unconsciously practice heat acclimation. Current data regarding hydration, EHI, and basic HA protocol knowledge among this population has been demonstrated to be low. Additionally, there have been no studies to date that have attempted to survey this populations' knowledge on more in-depth HA concepts and practices.

It is apparent that there is a need to gather information on recreational endurance athletes to determine if educational strategies need to be implemented on HA in this population. The purpose of this dissertation will be to assess the knowledge and practice of HA within the recreational population via two surveys. The surveys will consist of questions to gauge the recreational endurance athlete populations' specific knowledge in the realm of HA and their current training practices to determine conscious or unconscious knowledge and practice of HA.

CHAPTER III

KNOWLEDGE OF HEAT ACCLIMATION IN RECREATIONAL RUNNERS

Introduction

Heat Illness, among individuals performing physical activity in thermally stressful environments, is especially prevalent in the Southeastern United States (Harduar-Morano et al., 2015). Exertional heat illness (EHI) encompasses multiple health conditions that manifests with symptoms such as headache, nausea, and vomiting. Heat stroke and heat exhaustion are forms of EHI with core temperatures of > 40°C and < 40°C, respectively (Armstrong et al., 2007).

The National Athletic Trainers Association recommends Certified Athletic Trainers provide heat acclimation (HA) programs to athletes to reduce the occurrence of EHI (Casa et al., 2012). Heat acclimation results in physiological adaptations to hot and humid environments via repeated exposure, leading to better management of internal and external heat stress (Périard et al., 2016). Although various methods of HA exist, the physiological adaptations are similar, namely greater dissipation of heat from increased plasma volume and sweat rate, leading to greater potential evaporative cooling (Périard et al., 2015). Athletes often utilize HA training techniques in the weeks leading up to competitions in thermally stressful environments (Périard et al., 2015).

Professional athletes often have educated exercise science professionals assisting with performance enhancement and HA training protocols (Périard et al., 2017).

Conversely, recreationally active individuals may not have access to this same expertise. Hosokawa et al. (2019) determined in a sample of 2091 recreational runners, only 47.4% were aware of the correct duration of a HA protocol (Hosokawa et al., 2019). Additionally, Schendell et al. (2010) sampled 1,138 recreational marathon runners in the Southeastern United States and found 47.9% did not understand the risks of dying from heat stroke.

Recreational athletes have been found to receive most of their hydration advice from peers and it is possible that the same trend may occur for HA (O'Neal et al., 2011). Further, O'Neal et al. (2011) found nearly a quarter of the runners surveyed had experienced symptoms of EHI (O'Neal et al., 2011). With the prevalence of EHI among recreational athletes, in addition to data showing this population often engages in physical activity in dehydrated states (Bigg et al., 2019; Peacock et al., 2011), it is important recreational athletes be made aware of strategies to mitigate heat stress and reduce the risk of EHI during physical activity. If this population lacks knowledge in the realm of HA strategies, more educational material and initiatives are needed for the recreational athlete. Thus, the purpose of this study was to assess the recreational running population to determine knowledge of proper HA protocols, its associated benefits, and the sources where they receive HA information. A secondary purpose was to determine if any differences in HA knowledge are present among recreational runners of various fitness levels.

Methods

Participants

Participants were recruited via email lists for local running clubs in the Southeastern United States (U.S.) as well as by word of mouth with an electronic announcement that included a link to the survey on a hosting website (Qualtrics, Provo, Utah). Inclusion criteria included males and females between the ages of 18 and 70 years, running at least 3 times per week for at least 1 year and living and training in the Southeastern U.S. For this study, the states of South Carolina, North Carolina, Tennessee, Mississippi, Alabama, Georgia, and Florida were considered to make up the Southeastern U.S. based on Diem et al. (2017). Arkansas and Louisiana were additionally included based on their status as a humid sub-tropical climate (www.weather-us.com). All procedures were explained in an informed consent form at the start of the electronic survey. Participation was voluntary and participants were free to withdraw from the study at any time. The university Institutional Review Board (see Appendix A) approved all study procedures prior to data collection.

Questionnaire

The questionnaire included modified or adapted questions from previously used questionnaires along with original questions specific to the population being surveyed (Davis, 2018; Hosokawa et al., 2019; Macon, 2020; O'Neal et al., 2011; Periard et al. 2017; Shendell et al., 2010; Winger et al., 2010). The survey included 38 questions and required approximately 10-15 minutes to complete. The questionnaire included five sections: demographics, yearly training habits, HA and related topic knowledge, HA practices during the summer, and experiences with EHI. This manuscript includes results from the first three sections of the survey with focus on participant demographics, seasonal training, and HA knowledge.

Section one of the survey had nine questions on age, sex, education level, profession, geographic location, training and racing history, and participant's predicted current 10 km time. Section two included 12 questions on training practices throughout the year split into three questions per season. Specific questions included running intensity on a 0 - 10 rating of perceived exertion scale (Utter et al., 2004), running duration, as well as frequency, mileage, and running minutes per week. Section three of the survey included eight questions on participants' HA knowledge. Specific questions were asked regarding where HA information was acquired, past attempts at engaging in HA protocols, and perceived appropriate training frequency, exercise duration, exercise intensity, perceived appropriate training times during a summer day and benefits of HA, and whether participants' consistently run during the hottest part of the day during the summer in order to heat acclimate.

Statistical Analysis

All data were collected via Qualtrics software (Qualtrics, Provo, Utah, USA) and imported to SPSS version 27.0 (IBM Corp., Armonk, NY, USA) for analysis. Means ± *SD*s are reported for quantitative demographic variables and frequencies and percentages are reported for qualitative demographic variables. Participants were divided into thirds (low, moderate, and high training status) based on a product of summer training frequency, summer miles/wk, and predicted 10km time to determine if there were any differences in HA knowledge based on training volume. Welch's ANOVAs were performed on the quantitative responses and Chi-square Tests of Independence were performed on the qualitative responses to determine differences among training groups. A familywise alpha of $\leq .05$ was used for all analyses.

Results

A total of 216 surveys were collected with 125 meeting the inclusion criteria (N = 125) resulting in an approximate power of 0.70 for a medium effect size and alpha .05 for a one-way ANOVA. The sample included 55 males and 70 females with an average age of 44 years $\pm$ 12 years.

Demographics

Tables 1-3 provide details on participant characteristics, geographic location, and type of professional training guidance received, respectively. Almost half (46.4%) of participants reported having earned a graduate degree, while 40% of participants reported holding a bachelor’s degree, and 4.8% reported holding an associate degree. The remaining participants reported other forms of education (graduate school students, some college education, high school diploma).

Table 1

Participant Characteristics (N = 125)

Years Training (n = 122)	Years Racing (n = 119)	Predicted 10 km Time (min)	Training Status (n)		
			Low	Mod.	High
14.1 ± 11.5	13.1 ± 11.3	55.8 ± 13.3	44	41	40

Note. Training status calculated by participants predicted 10km Time and summer training volume.

Table 2

Geographic Distribution of Participants (*N* = 125)

State	*n*	% of Sample
Alabama	52	41.6
Tennessee	35	28.0
Louisiana	19	15.2
Arkansas	12	9.6
Florida	3	2.4
Georgia	2	1.6
Mississippi	1	0.8
South Carolina	1	0.8

Table 3

Professional Training Guidance and HA Information Sources (*N* = 125)

*Professional	*N*	% of Sample
Running coach	18	14.4
Athletic trainer	4	3.2
Strength and cond. spec.	4	3.2
Medical doctor	1	0.8
Other professional	7	5.6
No professional supervision	99	79.2
*HA information source		
Peers	39	31.2
Selected health professional such as doctors, athletic trainer	18	14.4
Current/former coaches, personal trainers, fitness instructors	33	26.4
Magazine, books, online articles	57	45.6
Peer reviewed research articles on training	12	9.6
Other source	7	5.6
Do not receive information regarding HA protocols	48	38.4

Note. *=Some participants reported receiving guidance from more than 1 type of professional / information source.

Yearly Training Habits

Table 4 includes training habits across different seasons for participants of low, moderate, and high training status. Significant differences between training groups were found for duration, frequency, mileage, and min/week within each season. No differences were found in training intensity among training groups for any season. Post hoc comparisons indicated that the low group ran with less frequency, mileage, minutes/week than the moderate and high groups for each season, with the moderate group reporting lower values for frequency, mileage, and min/week compared to the high group. Running duration was also found to be significantly lower in the low group than for the high group for each season, however there were no differences found when comparing the low group to the moderate group and the moderate group compared to the high group.

Heat Acclimation Knowledge

The first question of section 3 in the survey was "What are the benefits of a heat acclimation protocol? Check all that apply." Participants were required to correctly identify HA benefits out of 7 options, with 4 options being true and 3 options being false. A total of 3.2% (n = 4) of participants identified 3 options correctly, 30.4% (n = 38) identified 4 options correctly, 28.0% (n = 35) identified 5 options correctly, 27.2% identified 6 options correctly, and 11.2% (n = 14) of participants identified all 7 options correctly. The Welch ANOVA revealed no statistical differences in the number of correct responses among the training groups (F (2, 81.2) = 0.47; p = .63).

The second question of section 3 asked participants "Should runners attempt to follow a heat acclimation protocol by increasing running intensity, frequency, or duration in the summer (June 20th-September 19th)?" There was approximately equal split among the participants, with 64 (51.2%) respondents answering "yes" and 61 (48.8%) answering "no." The Chi-square test of independence reported no associations between the participants belief on whether a HA protocol should be followed and training status (N = 125; $\chi^2 = 4.41$; $p = .11$). The third question of section 3 asked participants "Should runners consistently exercise in the hottest part of the day during the summer?" An overwhelming majority of respondents (90.4%) answered "no," while the remaining (9.6%) answered "yes." The Chi-square test of independence indicated no association between training status and time of day to train for HA purposes (N = 125; $\chi^2 = 7.65$; $p = .47$).

The final question in section 3 asked participants "What time of day would you consider most appropriate to run at when attempting to heat acclimate?" The most common times for training were 9 am-11 am (28.8%; n =36), before 8 am (24%; n = 30), 3 pm-5 pm (23.2%; n = 29), and 6 pm-8 pm (8.8%; n =11) respectively. The Chi-square test of independence noted no association between time of day for training and training status (N = 125; $\chi^2 = 7.65$; $p = .47$).

Heat Acclimation Training Beliefs

Figure 1 presents the participants' perceptions on appropriate HA training protocols for the variables of duration, frequency, miles/wk, and RPE during the summer season.

Duration. Results from the Welch ANOVA revealed no significant differences among training groups for duration ($F(2, 122) = 1.87$, $p = .16$, $\eta_p^2 = .03$).

Frequency. Results from the Welch ANOVA revealed significant differences among training groups for frequency ($F(2, 122) = 13.88$, $p < .001$, $\eta_p^2 = .19$). Runners in the low group ($M = 3.03$) perceived training fewer days in a week to be appropriate for HA compared to both the moderate ($M = 3.77$, $M_{difference} = -.73$, 95% CI [-1.25, -0.22]) and the high group ($M = 4.16$, $M_{difference} = -1.12$; 95% CI [-1.65, -0.61]).

Mileage. Results from the Welch ANOVA revealed significant differences among training groups for mileage ($F(2, 121) = 28.42$, $p < .001$, $\eta_p^2 = .32$). Runners in the low group ($M = 11.76$) perceived running fewer miles/wk to be appropriate for HA compared to both the moderate ($M = 17.43$, $M_{difference} = -5.67$, 95% CI [-9.56, -1.79]) and the high group ($M = 24.18$; $M_{difference} = -12.41$, 95% CI = -16.33, -8.51]).

RPE. Results from the Welch ANOVA revealed no significant differences among training groups for RPE ($F(2, 122) = 1.33$, $p = .27$, $\eta_p^2 = .02$).

Min./wk. Results from the Welch ANOVA revealed significant differences among training groups for min/wk ($F(2, 121) = 12.17$, $p < .001$, $\eta_p^2 = .17$). Runners in the low group ($M = 113.02$) perceived running fewer min/wk to be appropriate for HA compared to both the moderate ($M = 166.59$, $M_{difference} = -53.56$, 95% CI [-104.65, -2.48]) and the high group ($M = 219.88$, $M_{difference} = -106.85$, 95% CI [-158.26, -55.44]).

Table 4

M ± *SDs* and Pairwise Comparisons in Seasonal Training Practices for Runners of Low, Moderate, and High Training Status. *N* = 125

	Summer			Fall		
	Low	Mod.	High	Low	Mod.	High
Duration	53.00 ± 17.70†	61.60 ± 20.50	71.00 ± 18.80	60.50 ± 20.10†	66.50 ± 21.20	72.30 ± 16.63
Frequency	3.70 ± 0.70*	4.90 ± 0.80†	5.90 ± 0.80	3.74 ± 0.83*	4.93 ± 0.86†	5.90 ± 0.88
Mileage	16.70 ± 4.40*	27.80 ± 6.30†	45.20 ± 12.00	19.20 ± 6.50*	31.00 ± 9.10†	45.30 ± 13.50
RPE	6.30 ± 1.70	5.90 ± 1.60	5.90 ± 1.30	5.80 ± 1.50	5.70 ± 1.60	6.10 ± 1.30
Min./wk	171.45 ± 56.62*	274.82 ± 74.72†	426.63 ± 138.25	191.67 ± 61.08*	298.72 ± 87.56†	429.81 ± 145.77
		Winter			Spring	
Duration	56.70 ± 18.20†	60.70 ± 22.60	70.20 ± 19.20	57.60 ± 18.50†	65.20 ± 22.30	69.80 ± 18.60
Frequency	3.70 ± 0.90*	4.50 ± 1.13†	5.80 ± 1.01	3.83 ± 0.75*	4.84 ± 0.88†	6.00 ± 0.84
Mileage	19.00 ± 8.20*	27.11 ± 9.50†	45.00 ± 14.30	19.00 ± 5.14	30.10 ± 9.01†	45.33 ± 11.93
RPE	5.60 ± 1.70	5.40 ± 1.70	6.10 ± 1.50	6.10 ± 1.41	5.90 ± 1.63	6.20 ± 1.30
Min./wk	184.42 ± 60.07*	262.08 ± 97.74†	412.56 ± 145.65	189.36 ± 54.09*	280.23 ± 85.00†	419.13 ± 140.39

Note. † Denotes a significant difference vs. the high group. * Denotes a significant difference vs. the moderate and high groups within a specific training season at $p \leq .05$. Significant differences based on a familywise alpha of .05 for each dependent variable.

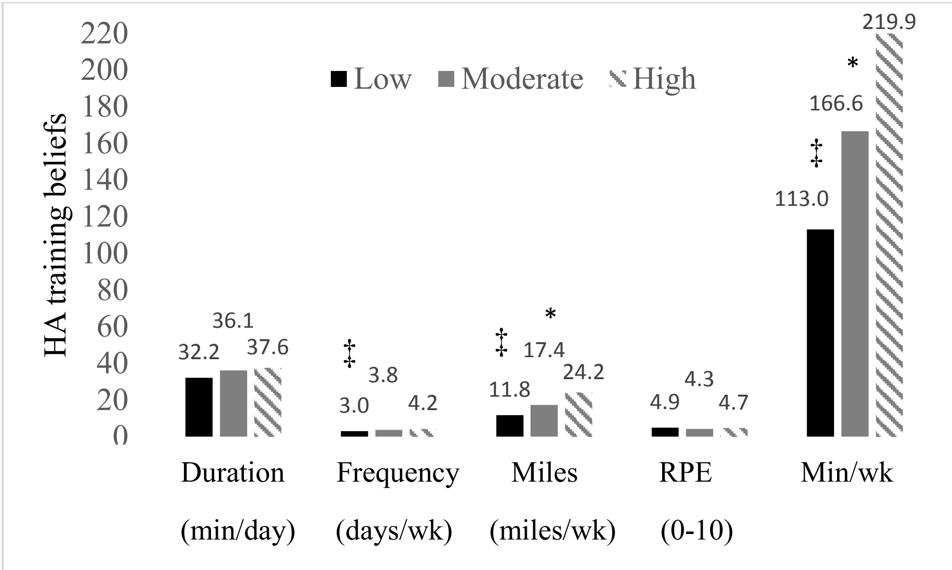

Figure 1. Participants' perception of appropriate HA training during the summer.

Note. ‡ Denotes significant differences between low vs. moderate and high training groups.* Denotes significant differences between mod. vs. high training groups at the $p < .05$ level. Freq. = frequency in days/wk. The y axis corresponds to minutes/run, days/wk, miles/wk, a RPE depending on the variable above. RPE = rating of perceived exertion.

Discussion

The purpose of this study was to determine the HA knowledge of a recreational running sample and to identify differences in knowledge among runners of varying training status. A sample of 125 (males = 55, females = 70) participants from the Southeastern United States responded to a survey consisting of 29 questions on training practices, HA knowledge, and HA information resources. Respondents were aged 44.6 ± 12.2 years and had an average training and racing experience of over a decade (see Table 1). Participants were primarily located in Alabama and Tennessee (see Table 2). Most runners in the sample reported training under no professional supervision (n = 99; 79.2%).

Most of the runners in the sample reported receiving HA advice from peers (n = 36; 31.2%), magazines, books, or online articles (45.6%), or not having received any information regarding HA (n = 48; 38.4%; Table 3). As expected, significantly lower values for seasonal training habits were found based on training status with the low training group training less frequently (days/week), with less volume (miles/week), and fewer total minutes per week than the moderate and high training groups, respectively. The moderate group reported lower values for the same variables than the high group for each respective training season (see Table 4).

While 30.4% of participants correctly identified approximately half of the true and false statements related to HA benefits, only 11.2% of participants correctly identified all 7 true and false HA benefit statements. These findings were further reflected in the participants opinions on HA protocols with almost half (48.8%) of the runners responding that runners should not follow an HA protocol during the summer season.

Significant differences were present by training status, with the low training group perceiving less training frequency appropriate for HA than the moderate and high groups, respectively. Finally, the appropriate mileage and min./wk reported for HA purposes significantly increased as training status increased (see Figure 1).

The current study demonstrates a lack of HA knowledge in the Southeastern recreational running population. This is especially concerning since the rate of heat related illness is higher in the Southeastern United States compared to other regions of the country (Morano et al., 2015). Because thermoregulatory ability is at least partially a result of aerobic fitness level, recreational running populations may be at higher risk of EHI compared to elite endurance athletes. Furthermore, with this population receiving HA information from their peers and not being guided by an exercise professional, it is hard to gauge whether scientifically accurate information is being disseminated.

The participants in the current study are comparable to those surveyed in previous studies by Davis (2018) and O'Neal et al. (2011) regarding age, training frequency, and weekly mileage. However, the current sample was older with more training experience when compared to the previously mentioned studies. Another difference in the current study is the race distance for which the participants were asked to estimate their finishing time. Participants in the current study were asked to estimate their current 10 km finishing time while those in O'Neal et al. (2011) were given a list of ranges to choose for both half-marathon (21.1 km) or marathon (42.2 km) distances. This decision was made in order to capture the biggest sample possible, as a greater percentage of recreational runners have possibly completed this distance as opposed to longer distances (i.e. half marathon and marathon), The trends regarding training volume are like those reported by Davis (2018; 18.7 - 62.4 miles) and O'Neal et al. (2011; 13.2 - 39.5 miles). Both past studies split participants into training groups based on various training related variables and lesser trained participants reported less training volume compared to their higher fit counterparts.

The finding in the current study that 79.2% of runners did not train under professional supervision is not surprising and agrees with past studies showing recreational runners predominantly train without professional supervision (Davis, 2018; O'Neal et al., 2011). This finding is further reflected in the responses regarding HA information sources. The three most common responses from respondents about sources of HA information in the current study were receiving advice from peers (31.2%), magazines, books, or online articles (45.6%), or receiving no advice at all (38.4%). Similar results were found in both Davis (2018) and O'Neal et al (2011) with a large portion of runners reporting that advice from their peers was deemed highly important,

Further expounding upon the current findings that recreational runners do not train under professional supervision and receive a large portion of information from their peers, it is not surprising that only 30.4% of participants correctly identified at least half of the true and false HA statements. The lack of HA knowledge is lower than that reported by Hosokawa et al. (2019), where only 47.4% of runners surveyed correctly identified an appropriate timeline to attain HA. Furthermore, only 51.5% of runners agreed that a person is more susceptible to exertional heatstroke in hot/humid environments. Others have also witnessed a lack of understanding in runners of the ramifications of experiencing heat stroke. Shendell et al. (2010) asked runners competing in a marathon in Atlanta, Georgia for their beliefs on the chances of dying after experiencing heat stroke. The recreational runners (47.9%) did not believe that the chances of death were over 20% (Shendell et al., 2010). The results of the current study, taken together with those of past studies, suggests there is a lack of information regarding HA, how it can help prevent EHI, and the health implications of experiencing EHI. Whether the findings of the current study are due to misinformed peers or inaccurate sources of information is beyond the scope of this study.

A recent study by Marocolo et al. (2021) found that of 33 social media accounts in Brazil providing exercise and training information, reaching an average of 30 million people, only 2.7% of these social media posts provided a peer-reviewed scientific citation. While many print or online resources may provide scientifically sound information, the current authors caution recreational runners who receive information from sources that do not provide scientific citations and from individuals who do not hold specific educational credentials needed to provide advice on HA.

Past data indicate greater than 50% of personal trainers do not receive training information from reputable sources (Bennie et al., 2017; Jolley et al., 2020). Bennie et al. (2017) also showed that of 1,185 fitness professionals surveyed, 56% received information from other fitness professionals and 62.5% developed their own ideas toward training. It has also been reported that while 79.3% of certified Athletic Trainers partially follow HA guidelines, only 3.9% fully follow guidelines (Kerr et al., 2019). Combined with the findings of the current study, it is possible that there is a lack of overall knowledge toward HA among fitness professionals and this may be a significant contributing factor to HA misinformation among recreational populations.

In the current sample approximately half of the participants reported HA training was appropriate during the summer season. When asked their beliefs on how a runner should become heat acclimated, the training groups differed in their opinions for frequency with the low group believing less frequency as more appropriate compared to the moderate and high groups and higher weekly mileage believed to be more appropriate in ascending order of training status (i.e., low, moderate, high; see Figure 1). Current HA guidelines recommend that exercise sessions last at least 60 min/day, have an intensity that produces an elevated core and skin temperature and causes the athlete to sweat, and lasts for 7 to 14 days (Racinais et al., 2015). Aside from exercise intensity, the 3 training groups in the current study failed to meet these guidelines when reporting their beliefs on an appropriate HA protocol. Although not statistically significant, there was a trend for more closely meeting HA guidelines the higher the training status of the participant.

These findings are important to note when examining EHI incidence in recreational running populations. O'Neal et al., (2011) found that 55% of recreational runners have experienced EHI symptoms in the past. Recreational runners are of lower fitness status than elite endurance athletes who have greater thermoregulatory abilities. The lack of HA knowledge found in the current study and EHI incidence rates found in the past combined with a lower aerobic fitness level within this population could pose a greater risk of EHI development when exercising in hot/humid environments.

Conclusion

The current study demonstrates that recreational runners in the Southeastern United States have a lack of knowledge toward HA and its associated benefits. Recreational runners are likely to receive information regarding HA training from their peers and sources that may not be scientifically accurate. This lack of knowledge is potentially dangerous when considering the summer training habits in hot/humid environments this population engages in and the lack of guidance they typically receive. It is recommended that more educational initiatives be created by governing bodies in exercise and sports to inform the recreational running population on the benefits and proper implementation of an HA program.

Chapter III References

Armstrong, L. E., Casa, D. J., Millard-Stafford, M., Moran, D. S., Pyne, S. W., & Roberts, W. O. (2007). Exertional heat illness during training and competition. *Medicine & Science in Sports & Exercise*, *39*(3), 556-572.

Bennie, J. A., Wiesner, G. H., van Uffelen, J. G., Harvey, J. T., & Biddle, S. J. (2017). Sources of practice knowledge among Australian fitness trainers. *Translational Behavioral Medicine*, *7*(4), 741-750.

Bigg, J. L., Gamble, A. S. D., Vermeulen, T. F., Boville, S. M., Eskedjian, G. S., Palmer, M. S., & Spriet, L. L. (2019). Sweat loss and hydration habits of female Olympic, varsity and recreational ice hockey players. *International Journal of Sports Medicine*, *40*(06), W416-W422.

Casa, D. J., Guskiewicz, K. M., Anderson, S. A., Courson, R. W., Heck, J. F., Jimenez, C. C., McDermott, B.P., Miller, M.G., Stearns, R.L., Swartz, E. E., & Walsh, K. M. (2012). National Athletic Trainers' Association position statement: Preventing sudden death in sports. *Journal of Athletic Training*, *47*(1), 96-118.

Centers for Disease Control. (1997). Monthly estimates of leisure-time physical inactivity--United States, 1994. *Morbidity and Mortality Weekly Report*, *46*, 393-397.

Davis, B. A. (2018). *Maintenance of health and distance running performance through hydration knowledge and practices* (Doctoral Dissertation, Middle Tennessee State University).

Diem, J. E., Stauber, C. E., & Rothenberg, R. (2017). Heat in the southeastern United States: Characteristics, trends, and potential health impact. *PloS One*, *12*(5), e0177937.

Harduar-Morano, L., Bunn, T. L., Lackovic, M., Lavender, A., Dang, G. T. T., Chalmers, J. J., Li, Y., Zhang, L. & Flammia, D. D. (2015). Occupational heat□related illness emergency department visits and inpatient hospitalizations in the southeast region, 2007–2011. *American Journal of Industrial Medicine*, *58*(10), 1114-1125.

Hosokawa, Y., Johnson, E. N., Jardine, J. F., Stearns, R. L., & Casa, D. J. (2019). Knowledge and belief toward heat safety and hydration strategies among runners: A preliminary evaluation. *Journal of Athletic Training*, *54*(5), 541-549.

Jolley, D. J., Davis, M., & Lavender, A. P. (2020). Misconceptions in the knowledge of vocational fitness students and graduates. *Australian Journal of Adult Learning*, *60*(1), 66-88.

Kerr, Z. Y., Register-Mihalik, J. K., Pryor, R. R., Hosokawa, Y., Scarneo-Miller, S. E., & Casa, D. J. (2019). Compliance with the National Athletic Trainers' Association Inter-Association Task Force preseason heat-acclimatization guidelines in high school football. *Journal of Athletic Training*, *54*(7), 749-757.

Macon, R. (2020). *The collegiate cross country and track and field coaches heat acclimation survey* (Master's Thesis, Middle Tennessee State University).

Marocolo, M., Meireles, A., de Souza, H. L. R., Mota, G. R., Oranchuk, D. J., Arriel, R. A., & Leite, L. H. R. (2021). Is social media spreading misinformation on exercise and health in Brazil? *International Journal of Environmental Research and Public Health*, *18*(22), 11914.

Matthews, C. E., Freedson, P. S., Hebert, J. R., Stanek III, E. J., Merriam, P. A., Rosal, M. C., ... & Ockene, I. S. (2001). Seasonal variation in household, occupational, and leisure time physical activity: longitudinal analyses from the seasonal variation of blood cholesterol study. *American Journal of Epidemiology*, *153*(2), 172-183.

O'Neal, E. K., Wingo, J. E., Richardson, M. T., Leeper, J. D., Neggers, Y. H., & Bishop, P. A. (2011). Half-marathon and full-marathon runners' hydration practices and perceptions. *Journal of Athletic Train*ing,46(6), 581–591.

Peacock, O. J., Stokes, K., & Thompson, D. (2011). Initial hydration status, fluid balance, and psychological affect during recreational exercise in adults. *Journal of Sports Sciences*, *29*(9), 897-904.

Périard, J. D., Racinais, S., & Sawka, M. N. (2015). Adaptations and mechanisms of human heat acclimation: Applications for competitive athletes and sports. *Scandinavian Journal of Medicine & Science in Sports*, *25*, 20-38.

Périard, J. D., Racinais, S., Timpka, T., Dahlström, Ö., Spreco, A., Jacobsson, J., Bargoria, V., Halje, K., & Alonso, J. M. (2017). Strategies and factors associated with preparing for competing in the heat: a cohort study at the 2015 IAAF World Athletics Championships. *British Journal of Sports Medicine*, *51*(4), 264-270.

Périard, J. D., Travers, G. J., Racinais, S., & Sawka, M. N. (2016). Cardiovascular adaptations supporting human exercise-heat acclimation. *Autonomic Neuroscience*, *196*, 52-62.

Tucker, P., & Gilliland, J. (2007). The effect of season and weather on physical activity: A systematic review. *Public Health*, *121*(12), 909-922.

Utter, A. C., Robertson, R. J., Green, J. M., Suminski, R. R., McAnulty, S. R., & Nieman, D. C. (2004). Validation of the adult OMNI scale of perceived exertion for walking/running exercise. *Medicine and Science in Sports and Exercise*, *36*(10), 1776-1780.

Shendell, D. G., Alexander, M. S., Lorentzson, L., & McCarty, F. A. (2010). Knowledge and awareness of heat-related morbidity among adult recreational endurance athletes. *International Journal of Biometeorology*, *54*(4), 441-448.

Winger, J. M., Dugas, J. P., & Dugas, L. R. (2011). Beliefs about hydration and physiology drive drinking behaviours in runners. *British Journal of Sports Medicine*, *45*(8), 646-649.

APPENDIX

APPENDIX A: IRB approval letter

IRB
INSTITUTIONAL REVIEW BOARD
Office of Research Compliance,
010A Sam Ingram Building,
2269 Middle Tennessee Blvd
Murfreesboro, TN 37129
FWA: 00005331/IRB Regn.. 0003571

MIDDLE TENNESSEE STATE UNIVERSITY

IRBN007 – EXEMPTION DETERMINATION NOTICE

Thursday, May 26, 2022

Protocol Title	***Heat Acclimation Knowledge and Practices Among Recreational Runners***
Protocol ID	**22-1054 2q**
Principal Investigator	**Alexander Heatherly** (Student) *Faculty Advisor:* Richard Farley
Co-Investigators	Jennifer Caputo, Samantha Johnson, and Dana Fuller
Investigator Email(s)	*ajh8h@mtmail.mtsu.edu; Richard.farley@mtsu.edu*
Department/Affiliation	Exercise Science, Health and Human Performance

Dear Investigator(s),

The above identified research proposal has been reviewed by the MTSU Institutional Review Board (IRB) through the **EXEMPT** review mechanism under 45 CFR 46.101(b)(2) within the research category ***(2) Educational Tests, surveys, interviews or observations of public behavior*** *(Qualtrics Survey)*. A summary of the IRB action and other particulars of this protocol are shown below:

IRB Action	**EXEMPT from further IRB Review** Exempt from further continuing review but other oversight requirements apply
Date of Expiration	**12/31/2022** *Date of Approval:* **10/13/21** *Recent Amendment:* **5/26/22**
Sample Size	TWO HUNDRED (200)
Participant Pool	**Healthy adults (18 or older) – Recreational Runners**
Exceptions	Online consent followed by internet-based survey using Qualtrics is permitted (Qualtrics links on file).
Type of Interaction	☐ Non-interventional or Data Analysis ☒ Virtual/Remote/Online Interview/survey ☐ In person or physical– Mandatory COVID-19 Management (refer next page)
Mandatory Restrictions	**1. All restrictions for exemption apply.** **2. The participants must be 18 years or older.** **3. Mandatory ACTIVE informed consent. Identifiable information including, names, addresses, voice/video data, must not be obtained.** **4. NOT approved for in-person data collection.**
Approved IRB Templates	*IRB Templates:* Recruitment Email and Online Informed Consent *Non-MTSU Templates:* Verbal Recruitment Script
Research Inducement	NONE
Comments	NONE

Summary of the Post-approval Requirements: The PI and FA must read and abide by the post-approval conditions (Refer "*Quick Links*" in the bottom):

- ***Final Report:*** The Faculty Advisor (FA) is responsible for submitting a final report to close-out this protocol before 12/31/2022; If more time is needed to complete the data collection, the FA must request an extension by email. REMINDERS WILL NOT BE SENT. **Failure to close-out (or request extension) may result in penalties** including cancellation of the data collected using this protocol or withholding student diploma.
- ***Protocol Amendments:*** IRB approval must be obtained for all types of amendments, such as:
  - Addition/removal of subject population and sample size.
  - Change in investigators.
  - Changes to the research sites – appropriate permission letter(s) from may be needed.
  - Alternation to funding.
  - Amendments must be clearly described in an addendum request form submitted by the FA.
  - The proposed change must be consistent with the approved protocol and they must comply with exemption requirements.
- ***Reporting Adverse Events:*** Research-related injuries to the participants and other events , such as, deviations & misconduct, must be reported within 48 hours of such events to compliance@mtsu.edu.
- ***Research Participant Compensation:*** Compensation for research participation must be awarded as proposed in Chapter 6 of the Exempt protocol. The documentation of the monetary compensation must Appendix J and MUST NOT include protocol details when reporting to the MTSU Business Office.
- ***COVID-19:*** Regardless whether this study poses a threat to the participants or not, refer to the COVID-19 Management section for important information for the FA.

COVID-19 Management:

The FA must enforce social distancing guidelines and other practices to avoid viral exposure to the participants and other workers when physical contact with the subjects is made during the study.

- The study must be stopped if a participant or an investigator should test positive for COVID-19 within 14 days of the research interaction. This must be reported to the IRB as an "adverse event."
- The FA must enforce the MTSU's "Return-to-work" questionnaire found in Pipeline must be filled and signed by the investigators on the day of the research interaction prior to physical contact.
- PPE must be worn if the participant would be within 6 feet from the each other or with an investigator.
- Physical surfaces that will come in contact with the participants must be sanitized between use
- **FA's Responsibility:** The FA is given the administrative authority to make emergency changes to protect the wellbeing of the participants and student researchers during the COVID-19 pandemic. However, the FA must notify the IRB after such changes have been made. The IRB will audit the changes at a later date and the PI will be instructed to carryout remedial measures if needed.

Post-approval Protocol Amendments:

The current MTSU IRB policies allow the investigators to implement minor and significant amendments that would not result in the cancellation of the protocol's eligibility for exemption. ***Only THREE procedural amendments will be entertained per year*** *(changes like addition/removal of research personnel are not restricted by this rule).*

Date	Amendment(s)	IRB Comments
05/26/2022	The target population's secondary definition is altered to include a wider age-range and geographic location(s). A revised recruitment script is approved to reflect this minor amendment.	IRBA2022-369

Post-approval IRB Actions:

The following actions are done subsequent to the approval of this protocol on request by the PI or on recommendation by the IRB or by both.

Date	IRB Action(s)	IRB Comments
NONE	NONE	NONE

Mandatory Data Storage Requirement:
All research-related records (signed consent forms, investigator training and etc.) must be retained by the PI or the faculty advisor (if the PI is a student) at the secure location mentioned in the protocol application. The data must be stored for at least three (3) years after the study is closed. Additionally, the Tennessee State data retention requirement may apply (*refer "Quick Links" below for policy 129*). Subsequently, the data may be destroyed in a manner that maintains confidentiality and anonymity of the research subjects. **The IRB reserves the right to modify/update the approval criteria or change/cancel the terms listed in this notice.** Be advised that IRB also reserves the right to inspect or audit your records if needed.

Sincerely,

Institutional Review Board
Middle Tennessee State University

Quick Links:
- Post-approval Responsibilities: http://www.mtsu.edu/irb/FAQ/PostApprovalResponsibilities.php
- Exemption Procedures: https://mtsu.edu/irb/ExemptPaperWork.php
- MTSU Policy 129: Records retention & Disposal: https://www.mtsu.edu/policies/general/129.php

CHAPTER IV

HEAT ACCLIMATION PRACTICES IN RECREATIONAL RUNNERS

Introduction

Repeated exposure to hot or humid environments results in physiological adaptations that assist in the mitigation of internal and external heat stress and improves cardiovascular function and performance during aerobic exercise (Périard et al., 2016). Heat acclimation (HA) is a common training technique used by professional coaches and trainers to provide a performance advantage to athletes in the weeks leading up to major competitions (Périard et al., 2017; Périard, et al., 2015). The National Athletic Trainers Association currently recommends athletes undergo HA over 1 - 2 weeks with special attention to hydration status along with close monitoring of athletes whose sport requires wearing special equipment that may impede evaporative heat loss (Casa et al., 2012). While elite athletes are known to utilize HA techniques to enhance performance and safety, little data have been gathered on the knowledge and practices of recreational athletes.

Current evidence toward the practices of HA in recreational athletes demonstrates these individuals have limited knowledge on heat stress safety and timelines of physiological adaptations to hot or humid environments (Hosokawa et al., 2019). Combined with data suggesting recreational athletes often exercise when dehydrated, the risk of heat illness in this population may be exacerbated compared to elite athletes (Bigg et al., 2019; Peacock et al., 2011). One practice that may exist among recreational populations, especially in the Southeastern United States, is subconscious practice of HA via continuation of regular training during seasonal transitions.

Although seasonal changes in training volume, aerobic fitness, and physical activity behavior are known to occur in elite endurance athletes as well as the general population (Losnegard et al., 2013; Sassi et al., 2008; Tucker & Gilliland, 2007), to the knowledge of the current authors, this trend has not been documented in recreationally trained endurance athletes. The Southeastern United States is categorized as a humid subtropical climate zone consisting of hot, humid summers and is conducive to thermoregulatory adaptations (Kottek et al., 2006; www.weather.gov). It is possible recreational athletes undergo HA naturally, without conscious implementation of specific strategies to induce environmental adaptations.

Natural HA has been documented in individuals whose occupations expose them to extreme environmental heat stress. Liu et al. (2014) examined wildland firefighters over a season to determine physiological adaptations to occupational and environmental heat stress using a pre- and post-season test protocol. Several physiological adaptations to the heat including decreased exercising core and skin temperatures were documented. Others have witnessed performance advantages in athletic events that have been attributed to country of origin and the associated climates. Ioannou et al. (2018) examined the performance of over 12,000 athletes from 78 countries who completed the Marathon des Sables in the Moroccan desert in the past 15 years. Runners who originated from countries with average temperatures between 15-35°C were 10.7% faster than those originating from countries with temperatures between -5-15°C. Furthermore, all first and second place winners and 81.3% of third place finishers originated from countries with higher ambient temperatures.

To the knowledge of the current authors, no researchers have assessed what portion of the recreational athlete population includes intentional or unintentional HA as part of their training program in an in-depth manner. Furthermore, the current training practices during seasonal transitions are not currently known in this population, which may or may not elicit a state of natural HA. Thus, the purpose of the current study was to determine the HA practices among a sample of recreational runners in the Southeast United States and determine if HA techniques are appropriately utilized and if there are any differences among individuals of different training status A secondary purpose was to determine if unconscious HA occurred due to changes in seasonal training.

Methods

Participants

Data collection occurred in the late summer and early fall between September and October. Recruitment occurred via email and word of mouth to running clubs in the Southeastern United States (U.S.) that included a study announcement and a link to the survey that was located on the hosting website (Qualtrics, Provo, Utah). Male and female participants were eligible to participate if they ran ≥ 3 days per week year-round, were between the ages of 18-70 years, and lived and trained in the Southeastern U.S. Eligible states included North Carolina, South Carolina, Tennessee, Mississippi, Alabama, Georgia, and Florida based on work from Diem et al. (2017). Arkansas and Louisiana were also included as eligible states based on its status as a humid, subtropical climate (www.weather-us.com). Prior to beginning the survey, participants electronically signed an informed consent form detailing study procedures along with the possible risks and benefits. Participants were free to withdraw from the study at any time. All methods were approved by the university Institutional Review Board (see Appendix A).

Heat Acclimation Practices Questionnaire

The questionnaire included 38 questions adapted from previous surveys along with original questions (Davis, 2018; Hosokawa et al., 2019; Macon, 2020; O'Neal et al., 2011; Periard et al. 2017; Shendell et al., 2010; Winger et al.,2010). The questionnaire was divided into five sections and this manuscript will address the final two sections of the survey related to HA practices and EHI symptoms and hydration practices.

The survey was designed to take 10-15 minutes to complete. Briefly, section one consisted of demographic questions where participants were asked their sex, age, education level, training and competition history, and geographic location where they trained and lived. Section two consisted of questions related to participant's running intensity, frequency, duration, mileage, and total running time/week for each season. Section three consisted of questions regarding participants' knowledge of HA protocols such as perceived appropriate frequency, intensity based on a 0-10 perceived exertion scale (Utter et al., 2004), and duration while running during the summer, sources where HA information is typically gathered (magazines, websites, research articles, coaches, etc.), perceived benefits of an HA protocol, past experiences with HA protocols, and most appropriate time of day to run for HA. Section four results are reported in this manuscript and involved questions related to the participant's current training habits during the summer including frequency, duration, intensity, mileage, and running minutes per week and how these factors may change when transitioning from spring to summer.

Participants were also queried on their preferred method of HA and time of day they train during the summer when attempting to HA. The final section of the survey, also included in this manuscript, consisted of questions pertaining to participants personal experiences of symptoms related to EHI such as dizziness, vomiting, nausea, headache, muscle cramps, etc., instances of ending training or races early due to overheating, decreases in performance due to overheating, fluid replacement before and during training in the heat, and pre and post training weighing to determine fluid losses.

Statistical Analysis

Data were collected via Qualtrics software (Qualtrics, Provo, Utah, USA) and imported to SPSS version 27.0 for analysis (IBM, Armonk, NY, USA). An a priori alpha of .05 was used for all statistical analyses. Participants were split into thirds corresponding to low, moderate, and high training groups based on a product of the participants' predicted 10km finishing time, summer training frequency, and summer training volume. To determine the HA practices of recreational runners and differences between training groups, different analyses were performed according to the question type. Frequencies are reported for the methods participants use to heat acclimate. Chi-square tests of independence were performed to determine differences in training groups for the qualitative HA practice questions (training volume changes when transitioning from spring to summer, time of day participants trained at during the summer) and EHI symptoms (performance decrements and prematurely ending training sessions, pre and during training hydration habits). A Welch's ANOVA was utilized to compare yearly frequency of heat illness related symptoms between training groups. To determine if unconscious HA occurs in the recreational running population due to seasonal training differences, a separate two-way RM ANOVA, with the Greenhouse-Geisser adjustment for sphericity violation, was performed for each training habit (frequency, intensity, mileage, minutes/week). A familywise alpha of .05 was used for all analyses.

Results

Dissemination of the survey resulted in 216 completed surveys. Of those 216, 125 met the inclusion criteria ($N = 125$) with a power of approximately 0.70 for a medium effect size and alpha of .05. In the sample, 55 respondents were male and 70 were female. The age of the sample was 44 years ± 12 years old, with participants reporting an average of over a decade of training (14 ± 11.5 years) and racing (13.1 ± 11.3 years) experience, and a predicted 10 km time of 55.8 ± 13.3 minutes.

Spring to Summer Transitions

The Chi-square test of independence noted no associations between training status (low, moderate, high) and spring to summer transitions (decrease, maintain, increase) for total mileage ($N = 119$; $\chi^2 = 7.08$; $p = .13$), duration ($N = 116$; $\chi^2 = 3.55$; $p = .47$), and intensity ($N = 119$; $\chi^2 = 9.18$; $p = .06$). However, an association was found based on training frequency ($N = 118$; $\chi^2 = 11.50$; $p = .02$). A total of 23.1% of the low group, 7.7% of the moderate group, and 5.0% of the high group decreased training frequency from spring to summer. A total of 5.1 % of the low group, 23.1% of the moderate group, and 12.5% of the high group increased training frequency. Finally, a total of 71.8% participants in the low, 69.2% in the moderate, and 82.5% in the high group maintained their training frequency.

Frequency data for the questions “At what time of day do you typically complete a training session during the summer if attempting to heat acclimate?” and “What methods do you use to acclimate to high heat or humidity?" can be found in Table 1. The Chi-square test of independence noted no associations between training status and time of day that the participants ran when attempting to heat acclimate ($N = 125$; $\chi^2 = 11.16$; $p = 0.19$).

Heat Illness Symptoms

Tables 2 and 3 contain results for the question "Indicate the yearly frequency at which you experience any of the following symptoms while running in high heat or humidity." There were no statistical differences found among training groups for any symptom although several variables demonstrated effect sizes that approached the moderate value of 0.5 as proposed by Cohen (1989).For example, , nausea was less common in the low group than in the high group and in the moderate group than in the high group and muscle cramps were less common in the low than the moderate group.

The responses to the question "Have you ever ended a training session or race due to symptoms of overheating" was almost evenly split with 49.6% ($n = 62$) answering "yes" and 50.4% ($n = 63$) answering "no" with no association by training group ($N = 125$; $\chi^2 = 2.64$; $p = .27$). For the question, "Have you ever felt your performance has suffered due to overheating during competition or training," 85.6% ($n = 107$) of participants answered "yes" and 14.4% ($n = 18$) answered "no" with no association being found for a training group and a specific response ($N = 125$; $\chi^2 = 2.10$; $p = .35$).

Table 1

Time of Day Participants Complete a Typical Summer Training Session and Preferred Method of HA

Time	*N*	% of *N*
Before 8 AM	52	41.6
9-11 AM	27	21.6
12-2 PM	17	13.6
3-5 PM	16	12.8
6-8 PM	13	10.4
HA method		
Outdoors	111	88.8
Climate chamber	1	0.8
Excess clothing	2	1.6
Hot water immersion	0	0
Sauna	8	6.4
Other method	4	3.2
Does not acclimate	20	16.0

Note. HA = heat acclimation. *denotes that some participants reported using multiple methods for HA.

Table 2

Yearly Occurrence of EHI Symptoms for Participants of Different Training Status

Symptom	Low	Moderate	High	Welch *F*	*p*
Nausea	1.09 ± 2.35	1.24 ± 2.13	2.74 ± 5.13	1.70 (2, 73.4)	.19
Vomiting	0.07 ± 0.45	0.30 ± 1.10	0.05 ± 0.22	1.00 (2, 67.5)	.36
Muscle cramps	1.57 ± 2.48	3.30 ± 5.01	2.47 ± 3.27	2.30 (2, 71.8)	.10
Headache	2.45 ± 4.45	1.99 ± 4.20	3.82 ± 8.75	0.70 (2, 73.0)	.50
Dizziness	1.40 ± 2.44	1.90 ± 3.74	3.19 ± 9.70	0.80 (2, 66.4)	.46
Lightheadedness	1.54 ± 2.43	2.25 ± 3.72	4.07 ± 12.20	1.20 (2, 64.7)	.31
Confusion	0.25 ± 1.36	0.13 ± 0.46	0.53 ± 1.92	0.92 (2, 63.0)	.40

Note. Values are $M \pm SD$. Low group n = 41-44, Moderate group n = 40-41, High group n = 38-40.

Table 3

Pairwise Comparisons of EHI Symptoms Among Training Groups

Comparisons	$M_{difference}$	95% CI mean differences [LL, UL]	*d*	95% CI d [LL, UL]
Nausea				
Low vs. Mod	-0.15	[-1.92, 1.61]	-0.07	[-0.49, 0.36]
Low vs. High	-1.65	[-3.44, 0.14]	-0.41	[-0.85, 0.02]
Mod vs. High	-1.50	[-3.32, 0.32]	-0.38	[-0.82, 0.06]
Vomiting				
Low vs. Mod	-0.23	[-0.60, 0.12]	-0.27	[-0.70, 0.15]
Low vs. High	0.02	[-0.35, 0.38]	0.06	[-0.38, 0.49]
Mod vs. High	0.25	[-0.12, 0.62]	0.32	[-0.13, 0.76]
Muscle cramps				
Low vs. Mod	-1.73	[-3.70, 0.21]	-0.44	[-0.87, 0.00]
Low vs. High	-0.90	[-2.87, 1.07]	-0.31	[-0.75, 0.13]
Mod vs. High	0.83	[-1.18, 2.83]	0.20	[-0.25, 0.64]
Headache				
Low vs. Mod	0.46	[-2.77, 3.70]	0.11	[-0.33, 0.54]
Low vs. High	-1.37	[-4.62, 1.88]	-0.20	[-0.64, 0.24]
Mod vs. High	-1.83	[-5.11, 1.44]	-0.27	[-0.71, 0.18]
Dizziness				
Low vs. Mod	-0.50	[-3.67, 2.66]	-0.16	[-0.59, 0.27]
Low vs. High	-1.79	[-4.98, 1.38]	-0.25	[-0.69, 0.18]
Mod vs. High	-1.29	[-4.53, 1.95]	-0.18	[-0.62, 0.27]
Lightheaded				
Low vs. Mod	-0.71	[-4.56, 3.13]	-0.23	[-0.66, 0.21]
Low vs. High	-2.53	[-6.43, 1.37]	-0.29	[-0.73, 0.15]
Mod vs. High	-1.82	[-5.76, 2.13]	-0.20	[-0.65, 0.24]
Confusion				
Low vs. Mod	0.12	[-0.59, 0.84]	0.12	[-0.31, 0.55]
Low vs. High	-0.28	[-0.99, 1.37]	-0.17	[-0.60, 0.26]
Mod vs. High	-0.40	[-1.14, 0.34]	-0.29	[-0.73, 0.15]

Note. Mod. = moderate group.

Hydration Questions

For the question “Do you consciously drink water or other beverages before training in hot/humid environments to ensure proper hydration,” 88.8% (n = 111) of participants stated that they drank water, 47.2% (n = 59) drank sports beverages, 10.4% (n = 13) drank “other,” and 0.8% (n = 1) of the participants reported not drinking anything before training. No association was found for training group and choosing water as a pre-exercise beverage (N = 125; χ^2 = 1.04; p = .60) or not drinking anything before exercise (N = 125; χ^2 = 1.86; p = .40). An association was found between training status and sports beverages (N = 125; χ^2 = 8.30; p = .02) with 34.1% of the low group, 43.9% of the moderate group, and 65.0% of the high group drinking a sports beverage pre-exercise. Additionally, an association was found between training group and the “other” type of beverage option (N = 125; χ^2 = 8.95; p = .01) with none of participants in the low group, 19.5% of the moderate group, and 12.5% of the high group drinking some other type of beverage pre-exercise.

For the question “Do you consciously drink water or other beverages during training in hot/humid environments to ensure proper hydration,” 83.2% (n = 104) reported drinking water, 51.2% (n = 64) reported drinking a sports beverage, 11.2% (n = 14) reported drinking “other,” and 4.8% (n = 6) reported that they did not drink during exercise in high heat/humidity. No association was found between training status and choosing to drink water during exercise (N = 125; χ^2 = .81; p = .67), drinking some other type of beverage during exercise (N = 125; χ^2 = 3.03; p = .22), and not drinking any beverage during exercise (N = 125; χ^2 = 3.79; p = .15). However, an association was found between training status and drinking a sports beverage during exercise (N = 125; χ^2

= 8.13; p = .02) with 36.4% of the low group, 51.2% of the moderate group, and 67.5% of the high group drinking a sports beverage during exercise in heat/humidity.

For the question, “Do you weigh yourself before and after runs during the summer months to assess sweat losses,” 64.8% (n = 81) of participants answered “no” and 36.2% (n = 44) answered “yes” with an association by training status (N =125; χ^2 = 6.83; p = 0.03). A total of 79.5% of the low group, 53.7% of the moderate group, 60% of the high group answered “no.” A total of 20.5% of the low, 46.3% of the moderate, and 40% of the high group answered “yes.”

Unconscious HA Practices

Duration. Descriptive data for training variables for all seasons can be found in Table 4. There was a main effect of season on training duration (F(2.4, 291.2) = 5.25; p = .003; η_p^2 =.04) with a greater duration in the fall (M = 66.45) compared to the summer (M = 61.87, $M_{difference}$ = 4.58, 95% CI [1.75, 7.41] and winter (M = 62.53, $M_{difference}$ = 3.92, 95% CI [0.18, 7.65]. No interaction effect of season and training group was present for duration (F(4.8, 291.2) = 1.28; p = .27; η_p^2 = .02).

Frequency. For training frequency, a main effect of season (F(2.4, 294.2) = 7.89; p < .001; η_p^2 =.06) and an interaction effect of season and training status (F(4.82 294.2) = 2.28; p = .049; η_p^2 = .04) were present. The low and high groups did not significantly alter their training frequency across seasons. For the moderate group, participants ran significantly more days in the summer (M = 4.88) compared to the winter (M = 4.46, $M_{difference}$ = 0.42, 95% CI [0.10, 0.73]), more days in the fall (M = 4.93) compared to the winter (M = 4.46, $M_{difference}$ = 0.46, 95% CI [0.19, 0.74]), and more days in the spring (M = 4.84) compared to winter (M = 4.46, $M_{difference}$ = 0.38, 95% CI [0.10, 0.65]).

Miles/wk. A main effect of season ($F(2.5, 309.7) = 3.70$; $p = .017$; $\eta_p^2 = .03$) was present with no interaction effect between season and training status ($F(5.1, 309.7) = 1.75$; $p = .122$; $\eta_p^2 = .03$). Participants ran more miles/wk in the fall ($M = 31.86$) compared to the summer ($M = 29.93$, $M_{difference} = 1.92$, 95% CI [0.34, 3.51]) and more miles in the spring ($M = 31.47$) compared to the summer ($M = 29.93$, $M_{difference} = 1.55$, 95% CI [0.17, 2.92]).

Min/wk. A main effect of season ($F(2.6, 302.6) = 4.80$, $p = .004$, $\eta_p^2 = .04$) was present with no interaction effect between season and training status ($F(5.17, 302.6) = 1.41$, $p = .219$, $\eta_p^2 = .02$). Participants ran more min/wk in the fall ($M = 305.84$) compared to the summer ($M = 291.05$, $M_{difference} = 14.80$, 95% CI [3.44, 26.16]) and ran more min/wk in the fall ($M = 305.84$) compared to the winter ($M = 287.10$, $M_{difference} = 18.75$, 95% CI [3.72, 33.79]).

RPE. A main effect of season was present ($F(1.8, 217.5) = 4.38$, $p = .017$, $\eta_p^2 = .04$) with no interaction effect between season and training status ($F(3.6, 217.5) = 1.74$, $p = .149$, $\eta_p^2 = .03$). Participants ran at a greater intensity in the spring ($M = 6.06$) compared to the fall ($M = 5.87$, $M_{difference} = 0.20$, 95% CI [0.01, 0.38]) and at a greater intensity in the spring compared to the winter ($M = 5.72$, $M_{difference} = 0.35$, 95% CI [0.12, 0.58]).

Table 4

M ± *SDs* for Training Variables Between Seasons within Respective Training Groups

	Summer			Fall		
	Low	Mod.	High	Low	Mod.	High
Duration	53.00 ± 17.70	61.60 ± 20.50	71.00 ± 18.80	60.50 ± 20.10	66.50 ± 21.20	72.30 ± 16.60
Frequency	3.70 ± 0.70	4.90 ± 0.80	5.90 ± 0.80	3.70 ± 0.80	4.90 ± 0.90	5.90 ± 0.90
Mileage	16.70 ± 4.40	27.80 ± 6.30	45.20 ± 12.00	19.20 ± 6.50	31.00 ± 9.10	45.30 ± 13.50
Intensity	6.30 ± 1.70	5.90 ± 1.60	5.90 ± 1.30	5.80 ± 1.50	5.70 ± 1.60	6.10 ± 1.30
Min./wk	170.77 ± 57.13	275.74 ± 75.51	426.62 ± 138.25	191.67 ± 61.08	296.05 ± 87.12	429.81 ± 145.77
	Winter			Spring		
Duration	56.70 ± 18.20	60.70 ± 22.60	70.20 ± 19.20	57.60 ± 18.50	65.20 ± 22.30	69.80 ± 18.60
Frequency	3.70 ± 0.90	4.50 ± 1.10	5.80 ± 1.00	3.80 ± 0.80	4.80 ± 0.90	6.00 ± 0.80
Mileage	19.00 ± 8.20	27.10 ± 9.50	45.00 ± 14.30	19.00 ± 5.10	30.10 ± 9.00	45.30 ± 11.90
Intensity	5.60 ± 1.70	5.40 ± 1.70	6.10 ± 1.50	6.10 ± 1.40	5.90 ± 1.60	6.20 ± 1.30
Min./wk	183.10 ± 60.16	265.61 ± 91.33	412.56 ± 145.65	189.11 ± 54.72	276.55 ± 84.86	419.13 ± 140.39

Discussion

The purpose of the current study was to determine HA practices of recreational runners in the Southeastern United States. A sample of 125 participants with an average age of 44 years ± 12 years old with over a decade of training and racing experience met inclusion criteria and provided data on their HA training practices, experience with symptoms of EHI, and pre/during exercise hydration habits. There were no associations between training status and changes from spring to summer for the training variable miles/wk, duration, and intensity. However, an association was found for training frequency with 23.1% of the low group decreasing training frequency and 23.1% of the moderate group increasing training frequency when transitioning from spring to summer. An association was found between training status and changes in frequency with 23.1% of the low group decreasing and 23.1% of the moderate group increasing their training frequency.

The main difference in the current study compared to previous studies of seasonal variations in exercise habits is the participants were split into training groups in this sample based on 10 km performance and summer training practices. While the participants in past studies were not strictly runners, the current authors propose that participants of the current study in the low to moderate training category may be comparable to the participants in investigations conducted by Dannenberg et al. (1989) and Pivarnick et al. (2003). Still, it is difficult to compare the participants across studies due to the current sample only including persons who perform aerobic exercise at least 3 times/week. When comparing the moderate training group of the current study to those of Dannenberg et al. (1989), the increase in exercise frequency in summer to winter is consistent. Additionally, the current findings that minimal changes in exercise intensity occur across seasons supports the findings of Pivarnick et al. (2003).

Despite the statistically significant differences observed across seasons for several training variables in the current study, the raw scores are similar across seasons and there is general consistency in the groups for training practices across seasons. Past studies have documented changes in training variables across seasons. Dannenberg et al. (1989) demonstrated women's physical activity (PA) frequency was significantly higher in the summer than the winter, with total weekly exercise minutes being higher in both sexes for summer versus winter. Additionally, Pivarnick et al, (2003) found adults were more active in the summer than in the winter, although exercise intensity as measured in metabolic equivalencies (METs) did not change. Pivarnick et al. (2003) concluded that the reason for higher activity levels in the summer than other seasons could be attributed to the finding that the lay person engages in multiple types of PA during this season.

This contrasts with elite endurance athletes, whose seasonal variations in training intensity and frequency are known to occur with concomitant decreases in training volume (Losnegard et al., 2013). The authors of the current study propose that recreational runners may maintain their training programs year-round due to lack of professional guidance or adequate training knowledge.

Another proposed explanation for seasonal differences in physical activity has been variations in environmental conditions and fitness level (CDC, A., 1994; Matthews et al., 2001). In the study by Matthews et al. (2001), participants who started engaging in regular exercise in the past 12 months had greater reductions in late summer PA vs. long-term exercisers who reported maintaining levels of PA into the fall season. Regarding the current study participants, it is possible that runners in the low training status group followed the same trend as those in Matthews et al., (2001) and therefore lowered their overall amount of training in response to seasonal changes. Furthermore, the findings in the current study that runners in the low training group performed less exercise duration, frequency, miles/wk, and minutes/wk compared to the high group across all seasons may also imply similar changes in training across seasons to those reported in Matthews et al., (2001). Finally, Tucker and Gilliland (2007) noted in their review of the effects of yearly seasons on PA that changes in PA across seasons varies based on a person's location of residency in the United States, with states that experience high levels of heat/humidity showing reductions in PA.

Regarding HA, the current authors propose it is possible participants in the moderate and high groups attained HA via maintenance of regular training practices. However, when examining the current guidelines for HA, only participants in the high training group are close to meeting current HA recommendations (Racinais et al., 2015). While the low group is lacking in training frequency to attain optimal HA, it is possible they may have a lower chance of developing EHI during exercise as their training and racing is likely not at as high of an intensity as their more physically active counterparts. Thus, attaining HA may not be as important for this population. Further studies are recommended to assess recreational runners of lower training levels to determine the need for HA training in their exercise program.

The current authors note that although no statistically significant differences were observed among training groups for experiences with EHI symptoms, examining the raw scores and effect sizes revealed runners who were more physically active experienced the symptoms of nausea and muscle cramps more often compared to the less physically active participants. The high group, by definition, performs more rigorous training regiments compared to the low group, thus it is not surprising they more frequently experience symptoms of EHI. This further supports the idea HA may be less important for low fit runners. However, roughly half of the participants in the current study reported having to stop a training session due to being overheated, with no association being found by training group.

In the current sample, 47.2% of participants drank sports beverages pre-exercise and 51.2% reporting drink sports beverages during exercise which is similar to previous samples (O'Neal et al., 2011). Furthermore, the association between sport beverage choice and the high training group mirror results of O'Neal et al. (2011). Roughly half (49.6%) of the participants reported feeling their performance suffered from symptoms of overheating and approximately 85% reported ending training/racing sessions due to overheating. Past studies have reported similar results in performance decrements and EHI symptoms. O'Neal et al., (2011) reported approximately 69% of participants felt their performance had been compromised due to dehydration, while 45% reported having experienced EHI symptoms. While in the current study it was examined if participants felt their performance suffered due to overheating and not specifically dehydration, one of the predisposing factors for EHI is dehydration which is relevant to the current discussion (Armstrong et al., 2007).

A total of 64.8% of participants in the current study reported they do not weigh themselves before and after runs to assess fluid losses with an association found based on training group, supporting previous research (Davis et al., 2018; O'Neal et al., 2011).

Assessing one's body mass via a store-bought scale is a practical and cost-effective method to ensure proper fluid replacement from exercise in a hot/humid environment. The data from the current study and O'Neal et al. (2011) imply many recreational runners do not have adequate knowledge of hydration assessment, which is an important factor for preventing EHI. This is also supported by past data showing recreational populations often perform in dehydrated states (Bigg et al., 2019; Peacock et al., 2011).

The finding that 88.8% of participants in the current study utilize the natural outdoor environment for HA purposes is expected due to its practicality and real-life application as competitive races are performed outdoors. However, it is interesting to note only 16% of participants stated they did not perform HA. Furthermore, the finding that 41.6% of the runners surveyed train before 8 am, when ambient temperatures tend to be cooler, may result in a removal of some of the environmental heat stimuli that is needed for positive adaptations related to HA. Taking this finding and comparing it to the seasonal training data, it appears the participants may perceive they are performing HA when they are not actually meeting current HA guidelines (Racinais et al., 2015). This further implies a lack of HA knowledge in the recreational running population. It is proposed that organizations in exercise and fitness should create educational initiatives regarding HA to better prepare the recreational population in implementing HA protocols into their training regiments.

While this study provides novel findings, there are limitations to address. Geographical limitations in generalization of findings specifically to the Southeastern United States have been proposed in the past (O'Neal et al, 2011). Additionally, the survey in the current study was designed to assess primarily HA practices and EHI symptom experience, thus the hydration assessment and hydration practices questions may not be adequate to make determinations of knowledge in those topics.

Conclusion

This recreationally running sample did not meet HA guidelines, despite their training staying consistent year-round and reporting they were engaging in a proper HA protocol. The participants' training consistency and reporting of proper HA practices are further compounded by their experiences with symptoms of overheating and EHI that leads to performance decrements and cessation of training in hot/humid environments. Additionally, it appears individuals who are less physically active, experience fewer yearly occurrences of EHI symptoms compared to individuals who are more physically active. Finally, this study supports conclusions that recreational running populations have little knowledge on assessing fluid losses after exercise, which may further enhance the risk of EHI. It is recommended recreational runners be educated on implementing a HA program into their regular training to reduce the risk of EHI in hot/humid environments.

Chapter IV References

Armstrong, L. E., Casa, D. J., Millard-Stafford, M., Moran, D. S., Pyne, S. W., & Roberts, W. O. (2007). Exertional heat illness during training and competition. *Medicine and Science in Sports and Exercise*, *39*(3), 556-572.

Bigg, J. L., Gamble, A. S. D., Vermeulen, T. F., Boville, S. M., Eskedjian, G. S., Palmer, M. S., & Spriet, L. L. (2019). Sweat loss and hydration habits of female Olympic, varsity and recreational ice hockey players. *International Journal of Sports Medicine*, *40*(06), 416-422.

Casa, D. J., Guskiewicz, K. M., Anderson, S. A., Courson, R. W., Heck, J. F., Jimenez, C. C., McDermott, B.P., Miller, M.G., Stearns, R.L., Swartz, E.E., & Walsh, K. M. (2012). National Athletic Trainers' Association position statement: Preventing sudden death in sports. *Journal of Athletic Training*, *47*(1), 96-118.

Davis, B. A. (2018). *Maintenance of health and distance running performance through hydration knowledge and practices* (Doctoral Dissertation, Middle Tennessee State University).

Dannenberg, A. L., Keller, J. B., Wilson, P. W., & Castelli, W. P. (1989). Leisure time physical activity in the Framingham Offspring Study: Description, seasonal variation, and risk factor correlates. *American Journal of Epidemiology*, *129*(1), 76-88.

Diem, J. E., Stauber, C. E., & Rothenberg, R. (2017). Heat in the southeastern United States: Characteristics, trends, and potential health impact. *PloS One*, *12*(5), e0177937.

Hosokawa, Y., Johnson, E. N., Jardine, J. F., Stearns, R. L., & Casa, D. J. (2019). Knowledge and belief toward heat safety and hydration strategies among runners: A preliminary evaluation. *Journal of Athletic Training*, *54*(5), 541-549.

Ioannou, L. G., Tsoutsoubi, L., Nybo, L., Tsianos, G. I., & Flouris, A. D. (2018). Habitual heat exposure and acclimatization associated with athletic performance in the multistage marathon des sables. *Journal of Human Performance in Extreme Environments*, *14*(1), Article 9.

Kottek, M., Grieser, J., Beck, C., Rudolf, B., & Rubel, F. (2006). World map of the Köppen-Geiger climate classification updated. *Meteorologische Zeitschrift, 15*(3), 259-263.

Lui, B., Cuddy, J. S., Hailes, W. S., & Ruby, B. C. (2014). Seasonal heat acclimatization in wildland firefighters. *Journal of Thermal Biology*, *45*, 134-140.

Losnegard, T., Myklebust, H., Spencer, M., & Hallén, J. (2013). Seasonal variations in VO2max, O2-cost, O2-deficit, and performance in elite cross-country skiers. *Journal of Strength and Conditioning Research*, *27*(7), 1780–1790.

Macon, R. (2020). *The collegiate cross country and track and field coaches heat acclimation survey* (Master's Thesis, Middle Tennessee State University).

O'Neal, E. K., Wingo, J. E., Richardson, M. T., Leeper, J. D., Neggers, Y. H., & Bishop, P. A. (2011). Half-marathon and full-marathon runners' hydration practices and perceptions. *Journal of Athletic Training*, *46*(6), 581-591.

Peacock, O. J., Stokes, K., & Thompson, D. (2011). Initial hydration status, fluid balance, and psychological affect during recreational exercise in adults. *Journal of Sports Sciences*, *29*(9), 897-904.

Périard, J. D., Racinais, S., & Sawka, M. N. (2015). Adaptations and mechanisms of human heat acclimation: Applications for competitive athletes and sports. *Scandinavian Journal of Medicine & Science in Sports*, *25*, 20-38.

Périard, J. D., Racinais, S., Timpka, T., Dahlström, Ö., Spreco, A., Jacobsson, J., Bargoria, V., Halje, K., & Alonso, J. M. (2017). Strategies and factors associated with preparing for competing in the heat: A cohort study at the 2015 IAAF World Athletics Championships. *British Journal of Sports Medicine*, *51*(4), 264-270.

Périard, J. D., Travers, G. J., Racinais, S., & Sawka, M. N. (2016). Cardiovascular adaptations supporting human exercise-heat acclimation. *Autonomic Neuroscience*, *196*, 52-62.

Pivarnik, J. M., Reeves, M. J., & Rafferty, A. P. (2003). Seasonal variation in adult leisure-time physical activity. *Medicine and Science in Sports and Exercise*, *35*(6), 1004-1008.

Racinais, S., Alonso, J. M., Coutts, A. J., Flouris, A. D., Girard, O., González□Alonso, J., ... & Périard, J. D. (2015). Consensus recommendations on training and competing in the heat. *Scandinavian Journal of Medicine & Science in Sports*, *25*, 6-19.

Sassi, A., Impellizzeri, F. M., Morelli, A., Menaspa, P., & Rampinini, E. (2008). Seasonal changes in aerobic fitness indices in elite cyclists. *Applied Physiology, Nutrition, and Metabolism*, *33*(4), 735-742.

Shendell, D. G., Alexander, M. S., Lorentzson, L., & McCarty, F. A. (2010). Knowledge and awareness of heat-related morbidity among adult recreational endurance athletes. *International Journal of Biometeorology*, *54*(4), 441-448.

Tucker, P., & Gilliland, J. (2007). The effect of season and weather on physical activity: A systematic review. *Public Health*, *121*(12), 909-922.

Utter, A. C., Robertson, R. J., Green, J. M., Suminski, R. R., McAnulty, S. R., & Nieman, D. C. (2004). Validation of the adult OMNI scale of perceived exertion for walking/running exercise. *Medicine and Science in Sports and Exercise*, *36*(10), 1776-1780.

Winger, J. M., Dugas, J. P., & Dugas, L. R. (2011). Beliefs about hydration and physiology drive drinking behaviours in runners. *British Journal of Sports Medicine*, *45*(8), 646-649.

APPENDIX

APPENDIX A: IRB approval letter

IRB
INSTITUTIONAL REVIEW BOARD
Office of Research Compliance,
010A Sam Ingram Building,
2269 Middle Tennessee Blvd
Murfreesboro, TN 37129
FWA: 00005331/IRB Regn.. 0003571

MIDDLE TENNESSEE STATE UNIVERSITY

IRBN007 – EXEMPTION DETERMINATION NOTICE

Thursday, May 26, 2022

Protocol Title	***Heat Acclimation Knowledge and Practices Among Recreational Runners***
Protocol ID	**22-1054 2q**
Principal Investigator	**Alexander Heatherly** (Student) *Faculty Advisor:* Richard Farley
Co-Investigators	Jennifer Caputo, Samantha Johnson, and Dana Fuller
Investigator Email(s)	*ajh8h@mtmail.mtsu.edu; Richard.farley@mtsu.edu*
Department/Affiliation	Exercise Science, Health and Human Performance

Dear Investigator(s),

The above identified research proposal has been reviewed by the MTSU Institutional Review Board (IRB) through the **EXEMPT** review mechanism under 45 CFR 46.101(b)(2) within the research category ***(2) Educational Tests, surveys, interviews or observations of public behavior*** *(Qualtrics Survey)*. A summary of the IRB action and other particulars of this protocol are shown below:

IRB Action	**EXEMPT from further IRB Review** Exempt from further continuing review but other oversight requirements apply
Date of Expiration	**12/31/2022** *Date of Approval:* **10/13/21** *Recent Amendment:* **5/26/22**
Sample Size	TWO HUNDRED (200)
Participant Pool	**Healthy adults (18 or older) – Recreational Runners**
Exceptions	Online consent followed by internet-based survey using Qualtrics is permitted (Qualtrics links on file).
Type of Interaction	☐ Non-interventional or Data Analysis ☒ Virtual/Remote/Online Interview/survey ☐ In person or physical– Mandatory COVID-19 Management (refer next page)
Mandatory Restrictions	**1. All restrictions for exemption apply.** **2. The participants must be 18 years or older.** **3. Mandatory ACTIVE informed consent. Identifiable information including, names, addresses, voice/video data, must not be obtained.** **4. NOT approved for in-person data collection.**
Approved IRB Templates	*IRB Templates:* Recruitment Email and Online Informed Consent *Non-MTSU Templates:* Verbal Recruitment Script
Research Inducement	NONE
Comments	NONE

Summary of the Post-approval Requirements: The PI and FA must read and abide by the post-approval conditions (Refer "*Quick Links*" in the bottom):

- ***Final Report:*** The Faculty Advisor (FA) is responsible for submitting a final report to close-out this protocol before **12/31/2022**; If more time is needed to complete the data collection, the FA must request an extension by email. REMINDERS WILL NOT BE SENT. **Failure to close-out (or request extension) may result in penalties** including cancellation of the data collected using this protocol or withholding student diploma.
- ***Protocol Amendments:*** IRB approval must be obtained for all types of amendments, such as:
  - Addition/removal of subject population and sample size.
  - Change in investigators.
  - Changes to the research sites – appropriate permission letter(s) from may be needed.
  - Alternation to funding.
  - Amendments must be clearly described in an addendum request form submitted by the FA.
  - The proposed change must be consistent with the approved protocol and they must comply with exemption requirements.
- ***Reporting Adverse Events:*** Research-related injuries to the participants and other events , such as, deviations & misconduct, must be reported within 48 hours of such events to compliance@mtsu.edu.
- ***Research Participant Compensation:*** Compensation for research participation must be awarded as proposed in Chapter 6 of the Exempt protocol. The documentation of the monetary compensation must Appendix J and MUST NOT include protocol details when reporting to the MTSU Business Office.
- ***COVID-19:*** Regardless whether this study poses a threat to the participants or not, refer to the COVID-19 Management section for important information for the FA.

COVID-19 Management:
The FA must enforce social distancing guidelines and other practices to avoid viral exposure to the participants and other workers when physical contact with the subjects is made during the study.

- The study must be stopped if a participant or an investigator should test positive for COVID-19 within 14 days of the research interaction. This must be reported to the IRB as an "adverse event."
- The FA must enforce the MTSU's "Return-to-work" questionnaire found in Pipeline must be filled and signed by the investigators on the day of the research interaction prior to physical contact.
- PPE must be worn if the participant would be within 6 feet from the each other or with an investigator.
- Physical surfaces that will come in contact with the participants must be sanitized between use
- **FA's Responsibility:** The FA is given the administrative authority to make emergency changes to protect the wellbeing of the participants and student researchers during the COVID-19 pandemic. However, the FA must notify the IRB after such changes have been made. The IRB will audit the changes at a later date and the PI will be instructed to carryout remedial measures if needed.

Post-approval Protocol Amendments:
The current MTSU IRB policies allow the investigators to implement minor and significant amendments that would not result in the cancellation of the protocol's eligibility for exemption. ***Only THREE procedural amendments will be entertained per year*** *(changes like addition/removal of research personnel are not restricted by this rule).*

Date	Amendment(s)	IRB Comments
05/26/2022	The target population's secondary definition is altered to include a wider age-range and geographic location(s). A revised recruitment script is approved to reflect this minor amendment.	IRBA2022-369

Post-approval IRB Actions:
The following actions are done subsequent to the approval of this protocol on request by the PI or on recommendation by the IRB or by both.

Date	IRB Action(s)	IRB Comments
NONE	NONE	NONE

Mandatory Data Storage Requirement:
All research-related records (signed consent forms, investigator training and etc.) must be retained by the PI or the faculty advisor (if the PI is a student) at the secure location mentioned in the protocol application. The data must be stored for at least three (3) years after the study is closed. Additionally, the Tennessee State data retention requirement may apply (*refer "Quick Links" below for policy 129*). Subsequently, the data may be destroyed in a manner that maintains confidentiality and anonymity of the research subjects. **The IRB reserves the right to modify/update the approval criteria or change/cancel the terms listed in this notice.** Be advised that IRB also reserves the right to inspect or audit your records if needed.

Sincerely,

Institutional Review Board
Middle Tennessee State University

Quick Links:
- Post-approval Responsibilities: http://www.mtsu.edu/irb/FAQ/PostApprovalResponsibilities.php
- Exemption Procedures: https://mtsu.edu/irb/ExemptPaperWork.php
- MTSU Policy 129: Records retention & Disposal: https://www.mtsu.edu/policies/general/129.php

CHAPTER V

Overall Conclusions

The overall purpose of this dissertation was to assess the HA training knowledge and practices of the recreational running population located in the Southeastern United States. A 38-question survey was designed to assess overall HA knowledge and training practices. The data were analyzed across runners of different training statuses in two studies. Study one was designed to assess the participants' HA knowledge and included demographics (age, sex, estimated 10km run time, etc.), geographic location (state of residence and training), HA information sources, and yearly training data. Study two incorporated data on the HA practices implored by the participants' (methods, time of day for training, etc.), overall yearly occurrence of EHI symptoms among participants, seasonal training differences, and pre- and post-exercise hydration.

Results of study one indicated a low level of HA knowledge among the recreational running population in the Southeastern United States. Main findings included the participants' reporting receiving most of their HA knowledge from their peers, most runners not receiving any professional supervision regarding training, and no sub-group of participants (low, moderate, or high training status) meeting current HA guidelines. These findings are problematic due to the humid sub-tropical climates the participants' typically train in during the summer which is known to increase the chance of EHI (Harduar-Marano et al., 2015; Kottek et al., 2006;). This, combined with the finding that most of the runners do not train under a qualified exercise professional who can educate and assist with HA programming, may put this population at higher risk of overheating during exercise in the summer season. Further educational initiatives and dissemination of scientifically sound information on HA targeted toward the recreational running population of the Southeastern United States is recommended to governing bodies of exercise and sports, in addition to other information sources (print/online publications) typically sought out by this population.

The main findings of study two were that participants believed they were practicing HA despite no sub-group of participants (low, moderate, or high training status) meeting current HA guidelines. The participants' training was consistent from season to season without adjustments that would typically be seen in a proper HA program. Participants who attempted to attain HA preferred running outdoors in the natural environment and 41.6%of runners reported running before 8am, where the heat stimuli would be lower. Approximately 85% of the participants reported ending a training session due to overheating with a trend for runners of higher training status more likely to experience symptoms of EHI. Finally, nearly two-thirds of participants reported not assessing pre- and post-exercise body mass to determine fluid losses.

Assessing the findings of each variable together demonstrates not only a lack of knowledge for proper HA in this population but also implies a lack of hydration knowledge and lack of periodized training practices. Although it may be argued that participants of lower training status may not be as susceptible to EHI, the finding that EHI symptoms tend to increase with increasing training status presents the likely possibility of greater EHI risk among moderate and highly trained runners. This is especially problematic given the finding that most participants (64.8%) reported not using a simple method of hydration assessment (body mass) pre- and post-exercise. These findings demonstrate a need for further educational initiatives by governing bodies of exercise and sports, exercise professionals, and various information sources to disseminate easily understandable hydration and EHI information to the recreational running population. This is needed to decrease their risk of EHI development during physical activity in areas with extreme environmental heat and humidity.

The findings of this dissertation identify a population that is in need of better education in the realm of exercise in the heat, proper hydration practices, and EHI prevention. Based on the current data and past findings, it is clear there has been a lack of easily understandable information on these topics for this subset of the running population. With HA being the foremost method of preventing EHI, it is imperative that individuals in the recreational population, who typically do not have access to professional coaching as demonstrated in the current studies, be provided with the best guidance and information available from accurate and reliable sources (Armstrong et al., 2007). This may ultimately lead to not only enhanced exercise performance but also greater safety when being physically active in hot, humid environments.

Dissertation References

Allan, J. R., & Wilson, C. G. (1971). Influence of acclimatization on sweat sodium concentration. *Journal of Applied Physiology*, *30*(5), 708-712.

Armstrong, L. E., Casa, D. J., Millard-Stafford, M., Moran, D. S., Pyne, S. W., & Roberts, W. O. (2007). Exertional heat illness during training and competition. *Medicine & Science in Sports & Exercise*, *39*(3), 556-572.

Armstrong, L. E., Francesconi, R. P., Kraemer, W. J., Leva, N., De Luca, J. P., & Hubbard, R. W. (1989). Plasma cortisol, renin, and aldosterone during an intense heat acclimation program. *International Journal of Sports Medicine*, *10*(01), 38-42.

Avellini, B. A., Kamon, E., & Krajewski, J. T. (1980). Physiological responses of physically fit men and women to acclimation to humid heat. *Journal of Applied Physiology*, *49*(2), 254-261.

Baker, L. B. (2019). Physiology of sweat gland function: The roles of sweating and sweat composition in human health. *Temperature*, *6*(3), 211-259.

Balmain, B. N., Sabapathy, S., Louis, M., & Morris, N. R. (2018). Aging and thermoregulatory control: the clinical implications of exercising under heat stress in older individuals. *BioMed Research International*, *2018*.

Bartelink, M. L., Wollersheim, H., Theeuwes, A., Van Duren, D., & Thien, T. (1990). Changes in skin blood flow during the menstrual cycle: The influence of the menstrual cycle on the peripheral circulation in healthy female volunteers. *Clinical Science*, *78*(5), 527-532.

Best, S., Thompson, M., Caillaud, C., Holvik, L., Fatseas, G., & Tammam, A. (2014). Exercise-heat acclimation in young and older trained cyclists. *Journal of Science and Medicine in Sport*, *17*(6), 677-682.

Bigg, J. L., Gamble, A. S. D., Vermeulen, T. F., Boville, S. M., Eskedjian, G. S., Palmer, M. S., & Spriet, L. L. (2019). Sweat loss and hydration habits of female Olympic, varsity and recreational ice hockey players. *International Journal of Sports Medicine*, *40*(06), 416-422.

Buono, M. J., Numan, T. R., Claros, R. M., Brodine, S. K., & Kolkhorst, F. W. (2009). Is active sweating during heat acclimation required for improvements in peripheral sweat gland function? *American Journal of Physiology-Regulatory, Integrative and Comparative Physiology*, *297*(4), R1082-R1085.

Casadio, J. R., Storey, A. G., Merien, F., Kilding, A. E., Cotter, J. D., & Laursen, P. B. (2017). Acute effects of heated resistance exercise in female and male power athletes. *European Journal of Applied Physiology*, *117*(10), 1965-1976.

Chen, T. I., Tsai, P. H., Lin, J. H., Lee, N. Y., & Liang, M. T. (2013). Effect of short-term heat acclimation on endurance time and skin blood flow in trained athletes. *Open Access Journal of Sports Medicine*, *4*, 161-170.

Cheung, S. S. (2010). Interconnections between thermal perception and exercise capacity in the heat. *Scandinavian Journal of Medicine & Science in Sports*, *20*, 53-59.

Chinevere, T. D., Kenefick, R. W., Cheuvront, S. N., Lukaski, H. C., & Sawka, M. N. (2008). Effect of heat acclimation on sweat minerals. *Medicine & Science in Sports & Exercise*, *40*(5), 886-891.

Collins, K. J., Crockford, G. W., & Weiner, J. S. (1966). The local training effect of secretory activity on the response of eccrine sweat glands. *The Journal of Physiology*, *184*(1), 203-214.

Corbett, J., Rendell, R. A., Massey, H. C., Costello, J. T., & Tipton, M. J. (2018). Inter-individual variation in the adaptive response to heat acclimation. *Journal of Thermal Biology*, *74*, 29-36.

Daanen, H. A., & Herweijer, J. A. (2015). Effectiveness of an indoor preparation program to increase thermal resilience in elderly for heat waves. *Building and Environment*, *83*, 115-119.

Donaldson, G. C., Keatinge, W. R., & Saunders, R. D. (2003). Cardiovascular responses to heat stress and their adverse consequences in healthy and vulnerable human populations. *International Journal of Hyperthermia*, *19*(3), 225-235.

Dougherty, K. A., Chow, M., & Kenney, W. L. (2009). Responses of lean and obese boys to repeated summer exercise heat bouts. *Medicine & Science in Sports & Exercise*, *41*(2), 279.

Eskandari, A., Fashi, M., Saeidi, A., Boullosa, D., Laher, I., Abderrahman, A. B., Jabbour, G. & Zouhal, H. (2020). Resistance exercise in a hot environment alters serum markers in untrained males. *Frontiers in Physiology*, *11,* Article 597.

Febbraio, M. A., Snow, R. J., Hargreaves, M., Stathis, C. G., Martin, I. K., & Carey, M. F. (1994). Muscle metabolism during exercise and heat stress in trained men: Effect of acclimation. *Journal of Applied Physiology*, *76*(2), 589-597.

Fox, R. H., Goldsmith, R., Hampton, I. F. G., & Lewis, H. E. (1964). The nature of the increase in sweating capacity produced by heat acclimatization. *The Journal of Physiology*, *171*(3), 368-376.

Fry, L. (2020). The effect of heat acclimatization, Heat acclimation, and intermittent exercise on aerobic performance. Master's Thesis, University of Connecticut.

Gagnon, D., & Kenny, G. P. (2012). Does sex have an independent effect on thermoeffector responses during exercise in the heat? *The Journal of Physiology*, *590*(23), 5963-5973.

Garden, J. W., Wilson, I. D., & Rasch, P. J. (1966). Acclimatization of healthy young adult males to a hot-wet environment. *Journal of Applied Physiology*, *21*(2), 665-669.

Garrett, A. T., Creasy, R., Rehrer, N. J., Patterson, M. J., & Cotter, J. D. (2012). Effectiveness of short-term heat acclimation for highly trained athletes. *European Journal of Applied Physiology*, *112*(5), 1827-1837.

Garrett, A. T., Dodd, E., Biddlecombe, V., Gleadall-Siddall, D., Burke, R., Shaw, J., Bray, J., Jones, H., Abt, G. & Gritt, J. (2019). Effectiveness of short-term heat acclimation on intermittent sprint performance with moderately trained females controlling for menstrual cycle phase. *Frontiers in Physiology*, *10*, Article 1458.

Garrett, A. T., Rehrer, N. J., & Patterson, M. J. (2011). Induction and decay of short-term heat acclimation in moderately and highly trained athletes. *Sports Medicine*, *41*(9), 757-771.

Gerrett, N., Ouzzahra, Y., Coleby, S., Hobbs, S., Redortier, B., Voelcker, T., & Havenith, G. (2014). Thermal sensitivity to warmth during rest and exercise: a sex comparison. *European Journal of Applied Physiology*, *114*(7), 1451-1462.

Guergova, S., & Dufour, A. (2011). Thermal sensitivity in the elderly: A review. *Ageing Research Reviews*, *10*(1), 80-92.

Gillen, C. M., Lee, Robert., Mack, G. W., Tomaselli, C. M., Nishiyasu, Takeshi., & Nadel, E. R. (1991). Plasma volume expansion in humans after a single intense exercise protocol. *Journal of Applied Physiology*, *71*(5), 1914-1920.

Gladden, L. B. (2019). Editorial note to Batterham and Hopkins letter and Sainani response. *Medicine & Science in Sports & Exercise*, *51*(3), 601-601.

Goto, K., Oda, H., Kondo, H., Igaki, M., Suzuki, A., Tsuchiya, S., Murase, T., Hase, T., Fujiya, H., Matsumoto, I., Naito, H., Sugiura, T., Ohira, Y. & Yoshioka, T. (2011). Responses of muscle mass, strength, and gene transcripts to long-term heat stress in healthy human subjects. *European Journal of Applied Physiology*, *111*(1), 17-27.

Harduar Morano, L., T. L. Bunn, M. Lackovic, A. Lavender, G. T. T. Dang, J. J. Chalmers, Yun Li, Linhe Zhang, & D. D. Flammia. (2015). Occupational heat□related illness emergency department visits and inpatient hospitalizations in the southeast region, 2007–2011. *American Journal of Industrial Medicine,* 58(10), 1114-1125.

Hargreaves, M., Angus, D., Howlett, K., Conus, N. M., & Febbraio, M. (1996). Effect of heat stress on glucose kinetics during exercise. *Journal of Applied Physiology*, *81*(4), 1594-1597.

Hodge, D., Jones, D., Martinez, R., & Buono, M. J. (2013). Time course of the attenuation of sympathetic nervous activity during active heat acclimation. *Autonomic Neuroscience*, *177*(2), 101-103.

Hosokawa, Y., Johnson, E. N., Jardine, J. F., Stearns, R. L., & Casa, D. J. (2019). Knowledge and belief toward heat safety and hydration strategies among runners: A preliminary evaluation. *Journal of Athletic Training*, *54*(5), 541-549.

Hew-Butler, T. (2010). Arginine vasopressin, fluid balance and exercise. *Sports Medicine*, *40*(6), 459-479.

Inbar, O., Bar-Or, O., Dotan, R., & Gutin, B. (1981). Conditioning versus exercise in heat as methods for acclimatizing 8-to 10-yr-old boys to dry heat. *Journal of Applied Physiology*, *50*(2), 406-411.

Inbar, O., Dotan, R., Bar-Or, O., & Gutin, B. (1985). Passive versus active exposures to dry heat as methods of heat acclimatization in young children. *Children and Exercise XI*, 329-340.

Inoue, Y., Gerrett, N., Ichinose-Kuwahara, T., Umino, Y., Kiuchi, S., Amano, T., Ueda, H., Havenith, G., & Kondo, N. (2016). Sex differences in age-related changes on peripheral warm and cold innocuous thermal sensitivity. *Physiology & Behavior*, *164*, 86-92.

Inoue, Y., Havenith, G., Kenney, W. L., Loomis, J. L., & Buskirk, E. R. (1999). Exercise-and methylcholine-induced sweating responses in older and younger men: effect of heat acclimation and aerobic fitness. *International Journal of Biometeorology*, *42*(4), 210-216.

Karlsen, A., Racinais, S., Jensen, M. V., Nørgaard, S. J., Bonne, T., & Nybo, L. (2015). Heat acclimatization does not improve VO2max or cycling performance in a cool climate in trained cyclists. *Scandinavian Journal of Medicine & Science in Sports*, *25*, 269-276.

Keiser, S., Flück, D., Hüppin, F., Stravs, A., Hilty, M. P., & Lundby, C. (2015). Heat training increases exercise capacity in hot but not in temperate conditions: A mechanistic counter-balanced cross-over study. *American Journal of Physiology-Heart and Circulatory Physiology*, *309*(5), H750-H761.

Kenny, G. P., Poirier, M. P., Metsios, G. S., Boulay, P., Dervis, S., Friesen, B. J., Malcolm, J., Sigal, R.J., Seely, A.J.E. & Flouris, A. D. (2017). Hyperthermia and cardiovascular strain during an extreme heat exposure in young versus older adults. *Temperature*, *4*(1), 79-88.

Kim, K., Reid, B. A., Casey, C. A., Bender, B. E., Ro, B., Song, Q., Trewin, A.J., Petersen, A.C., Kuang, S., Gavin, T.P. & Roseguini, B. T. (2020). Effects of repeated local heat therapy on skeletal muscle structure and function in humans. *Journal of Applied Physiology*, *128*(3), 483-492.

King, D. S., Costill, D. L., Fink, W. J., Hargreaves, M., & Fielding, R. A. (1985). Muscle metabolism during exercise in the heat in unacclimatized and acclimatized humans. *Journal of Applied Physiology*, *59*(5), 1350-1354.

Kirby, C. R., & Convertino, V. A. (1986). Plasma aldosterone and sweat sodium concentrations after exercise and heat acclimation. *Journal of Applied Physiology*, *61*(3), 967-970.

Kirby, N. V., Lucas, S. J., & Lucas, R. A. (2019). Nine, but not four-days heat acclimation improves self-paced endurance performance in females. *Frontiers in Physiology*, *10*, Article 539.

Kirwan, J. P., Costill, D. L., Kuipers, H. A. R. M., Burrell, M. J., Fink, W. J., Kovaleski, J. E., & Fielding, R. A. (1987). Substrate utilization in leg muscle of men after heat acclimation. *Journal of Applied Physiology*, *63*(1), 31-35.

Kottek, M., Grieser, J., Beck, C., Rudolf, B., & Rubel, F. (2006). World map of the Köppen-Geiger climate classification updated. *Meteorologische Zeitschrift, 15*(3), 259-263.

Larose, J., Wright, H. E., Stapleton, J., Sigal, R. J., Boulay, P., Hardcastle, S., & Kenny, G. P. (2013). Whole body heat loss is reduced in older males during short bouts of intermittent exercise. *American Journal of Physiology-Regulatory, Integrative and Comparative Physiology*, *305*(6), R619-R629.

Larose, J., Boulay, P., Wright-Beatty, H. E., Sigal, R. J., Hardcastle, S., & Kenny, G. P. (2014). Age-related differences in heat loss capacity occur under both dry and humid heat stress conditions. *Journal of Applied Physiology*, *117*(1), 69-79.

Levels, K., de Koning, J. J., Foster, C., & Daanen, H. A. (2012). The effect of skin temperature on performance during a 7.5-km cycling time trial. *European Journal of Applied Physiology*, *112*(9), 3387-3395.

Lorenzo, S., Halliwill, J. R., Sawka, M. N., & Minson, C. T. (2010). Heat acclimation improves exercise performance. *Journal of Applied Physiology*, *109*(4), 1140-1147.

Lohse, K. R., Sainani, K. L., Taylor, J. A., Butson, M. L., Knight, E. J., & Vickers, A. J. (2020). Systematic review of the use of “magnitude-based inference” in sports science and medicine. *PloS One*, *15*(6), e0235318.

Macon, R. (2020). *The Collegiate Cross Country and Track and Field Coaches Heat Acclimation Survey* (Order No. 28155429). Available from ProQuest Dissertations & Theses Global. (2465335239). https://ezproxy.mtsu.edu/login

Magalhães, F. C., Passos, R. L., Fonseca, M. A., Oliveira, K. P., Ferreira-Júnior, J. B., Martini, A. R., Lima, M.R.M, Guimarães, J.B., Baraúna, V.G., Silami-Garcia, E. & Rodrigues, L.O.C (2010). Thermoregulatory efficiency is increased after heat acclimation in tropical natives. *Journal of Physiological Anthropology*, *29*(1), 1-12.

Mazerolle, S. M., Scruggs, I. C., Casa, D. J., Burton, L. J., McDermott, B. P., Armstrong, L. E., & Maresh, C. M. (2010). Current knowledge, attitudes, and practices of certified athletic trainers regarding recognition and treatment of exertional heat stroke. *Journal of Athletic Training*, *45*(2), 170-180.

Mee, J. A., Gibson, O. R., Doust, J., & Maxwell, N. S. (2015). A comparison of males and females' temporal patterning to short□and long□term heat acclimation. *Scandinavian Journal of Medicine & Science in Sports*, *25*, 250-258.

Mikkelsen, C. J., Junge, N., Piil, J. F., Morris, N. B., Oberholzer, L., Siebenmann, C., Lundby, C. & Nybo, L. (2019). Prolonged heat acclimation and aerobic performance in endurance trained athletes. *Frontiers in Physiology*, *10*, Article 1372.

Miles, C., Mayo, B., Beaven, C. M., McMaster, D. T., Sims, S. T., Hébert-Losier, K., & Driller, M. (2019). Resistance training in the heat improves strength in professional rugby athletes. *Science and Medicine in Football*, *3*(3), 198-204.

Millyard, A., Layden, J. D., Pyne, D. B., Edwards, A. M., & Bloxham, S. R. (2020). Impairments to Thermoregulation in the Elderly During Heat Exposure Events. *Gerontology and Geriatric Medicine, 6*. https://doi.org/10.1177/2333721420932432

Neal, R. A., Massey, H. C., Tipton, M. J., Young, J. S., & Corbett, J. (2016). Effect of permissive dehydration on induction and decay of heat acclimation, and temperate exercise performance. *Frontiers in Physiology*, *7*, Article 564.

Nichols, A. W. (2014). Heat-related illness in sports and exercise. *Current Reviews in Musculoskeletal Medicine*, *7*(4), 355-365.

Nielsen, B., Hales, J. R., Strange, S., Christensen, N. J., Warberg, J., & Saltin, B. (1993). Human circulatory and thermoregulatory adaptations with heat acclimation and exercise in a hot, dry environment. *The Journal of Physiology*, *460*(1), 467-485.

Nielsen, B., Strange, S., Christensen, N. J., Warberg, J., & Saltin, B. (1997). Acute and adaptive responses in humans to exercise in a warm, humid environment. *Pflügers Archiv*, *434*(1), 49-56.

Notley, S. R., Akerman, A. P., Meade, R. D., McGarr, G. W., & Kenny, G. P. (2020). Exercise thermoregulation in prepubertal children: A brief methodological review. *Medicine & Science in Sports & Exercise*, *52*(11), 241-2422.

Nybo, L., & Lundby, C. (2016). CrossTalk opposing view: Heat acclimatization does not improve exercise performance in a cool condition. *The Journal of Physiology*, *594*(2), 245-247.

Oberholzer, L., Siebenmann, C., Mikkelsen, C. J., Junge, N., Piil, J. F., Morris, N. B., Goetze, J.P., Lundby, A.K.M., Nybo, L. & Lundby, C. (2019). Hematological adaptations to prolonged heat acclimation in endurance-trained males. *Frontiers in Physiology*, *10*, Article 1379.

O'Neal, E. K., Wingo, J. E., Richardson, M. T., Leeper, J. D., Neggers, Y. H., & Bishop, P. A. (2011). Half-marathon and full-marathon runners' hydration practices and perceptions. *Journal of Athletic Training*, *46* (6): 581–591.

Parkin, J. M., Carey, M. F., Zhao, S., & Febbraio, M. A. (1999). Effect of ambient temperature on human skeletal muscle metabolism during fatiguing submaximal exercise. *Journal of Applied Physiology*, *86*(3), 902-908.

Parton, A. J., Waldron, M., Clifford, T., & Jeffries, O. (2021). Thermo-behavioral responses to orally applied L-menthol exhibit sex-specific differences during exercise in a hot environment. *Physiology & Behavior*, *229*, Article 113250.

Peacock, O. J., Stokes, K., & Thompson, D. (2011). Initial hydration status, fluid balance, and psychological affect during recreational exercise in adults. *Journal of Sports Sciences*, *29*(9), 897-904.

Périard, J. D., Racinais, S., & Sawka, M. N. (2015). Adaptations and mechanisms of human heat acclimation: applications for competitive athletes and sports. *Scandinavian Journal of Medicine & Science in Sports*, *25*, 20-38.

Périard, J. D., Racinais, S., Timpka, T., Dahlström, Ö., Spreco, A., Jacobsson, J., Bargoria, V., Halje, K., & Alonso, J. M. (2017). Strategies and factors associated with preparing for competing in the heat: A cohort study at the 2015 IAAF World Athletics Championships. *British Journal of Sports Medicine*, *51*(4), 264-270.

Périard, J. D., Travers, G. J., Racinais, S., & Sawka, M. N. (2016). Cardiovascular adaptations supporting human exercise-heat acclimation. *Autonomic Neuroscience*, *196*, 52-62.

Powers, S. K., Howley, E. T. (2018). *Exercise physiology: Theory and application to fitness and performance*. McGraw-Hill.

Racinais, S., Alonso, J. M., Coutts, A. J., Flouris, A. D., Girard, O., González□Alonso, J., Hausswirth, C., Jay, O., Lee, J.K.W., Mitchell, N., Nassis, G.P., Nybo, L., Pluim, B.M., Roelands, B., Sawka, M.N., Wingo, J., & Périard, J. D. (2015). Consensus recommendations on training and competing in the heat. *Scandinavian Journal of Medicine & Science in Sports*, *25*, 6-19.

Racinais, S., Périard, J. D., Karlsen, A., & Nybo, L. (2015). Effect of heat and heat acclimatization on cycling time trial performance and pacing. *Medicine and Science in Sports and Exercise*, *47*(3), 601-606.

Racinais, S., Sawka, M., Daanen, H., & Périard, J. D. (2019). Heat acclimation. In *Heat Stress in Sport and Exercise* (pp. 159-178). Springer.

Rahimi, G. R. M., Albanaqi, A. L., Van der Touw, T., & Smart, N. A. (2019). Physiological responses to heat acclimation: a systematic review and meta-analysis of randomized controlled trials. *Journal of Sports Science & Medicine*, *18*(2), 316-326.

Sainani, K. L. (2018). The Problem with" Magnitude-based Inference". *Medicine & Science in Sports & Exercise*, *50*(10), 2166-2176.

Sato, K., & Dobson, R. L. (1970). The effect of intracutaneous d-aldosterone and hydrocortisone on human eccrine sweat gland function. *Journal of Investigative Dermatology*, *54*(6), 450-462.

Sawka, M. N., Young, A. J., Cadarette, B. S., Levine, L., & Pandolf, K. B. (1985). Influence of heat stress and acclimation on maximal aerobic power. *European Journal of Applied Physiology and Occupational Physiology*, *53*(4), 294-298.

Schlader, Z. J., Simmons, S. E., Stannard, S. R., & Mündel, T. (2011). Skin temperature as a thermal controller of exercise intensity. *European Journal of Applied Physiology*, *111*(8), 1631-1639.

Schweiker, M., Huebner, G. M., Kingma, B. R., Kramer, R., & Pallubinsky, H. (2018). Drivers of diversity in human thermal perception – A review for holistic comfort models. *Temperature*, *5*(4), 308-342.

Shapiro, Y., Pandolf, K. B., Avellini, B. A., Pimental, N. A., & Goldman, R. F. (1980). Physiological responses of men and women to humid and dry heat. *Journal of Applied Physiology*, *49*(1), 1-8.

Shendell, D. G., Alexander, M. S., Lorentzson, L., & McCarty, F. A. (2010). Knowledge and awareness of heat-related morbidity among adult recreational endurance athletes. *International Journal of Biometeorology*, *54*(4), 441-448.

Shibasaki, M., Okazaki, K., & Inoue, Y. (2013). Aging and thermoregulation. *The Journal of Physical Fitness and Sports Medicine*, *2*(1), 37-47.

Sotiridis, A., Debevec, T., Ciuha, U., Eiken, O., & Mekjavic, I. B. (2019). Heat acclimation does not affect maximal aerobic power in thermoneutral normoxic or hypoxic conditions. *Experimental Physiology*, *104*(3), 345-358.

Stacey, M. M. J., Delves, S. K., Woods, D. R., Britland, S. E., Macconnachie, L., Allsopp, A. J., Brett, S. J., Fallowfield, J. L. & Boos, C. J. (2018). Heart rate variability and plasma nephrines in the evaluation of heat acclimatization status. *European Journal of Applied Physiology*, *118*(1), 165-174.

Stadnyk, A. M., Rehrer, N. J., Handcock, P. J., Meredith-Jones, K. A., & Cotter, J. D. (2018). No clear benefit of muscle heating on hypertrophy and strength with resistance training. *Temperature*, *5*(2), 175-183.

Starkie, R. L., Hargreaves, M., Lambert, D. L., Proietto, J., & Febbraio, M. A. (1999). Effect of temperature on muscle metabolism during submaximal exercise in humans. *Experimental \Physiology*, *84*(4), 775-784.

Takamata, A., Ito, T., Yaegashi, K., Takamiya, H., Maegawa, Y., Itoh, T., Greenleaf, J. E. & Morimoto, T. (1999). Effect of an exercise-heat acclimation program on body fluid regulatory responses to dehydration in older men. *American Journal of Physiology-Regulatory, Integrative and Comparative Physiology*, *277*(4), R1041-R1050.

Tankersley, C. G., Smolander, J., Kenney, W. L., & Fortney, S. M. (1991). Sweating and skin blood flow during exercise: effects of age and maximal oxygen uptake. *Journal of Applied Physiology*, *71*(1), 236-242.

Travers, G., González-Alonso, J., Riding, N., Nichols, D., Shaw, A., & Periard, J. D. (2020). Exercise heat acclimation has minimal effects on left ventricular volumes, function and systemic hemodynamics in euhydrated and dehydrated trained humans. *American Journal of Physiology-Heart and Circulatory Physiology*, *319*(5), H965-H979.

Travers, G., Nichols, D., Riding, N., González-Alonso, J., & Périard, J. D. (2020). Heat acclimation with controlled heart rate: Influence of hydration status. *Medicine & Science in Sports & Exercise*, *52*(8), 1815-1824.

Tucker, R. (2009). The anticipatory regulation of performance: the physiological basis for pacing strategies and the development of a perception-based model for exercise performance. *British Journal of Sports Medicine*, *43*(6), 392-400.

Tyler, C. J., Reeve, T., Hodges, G. J., & Cheung, S. S. (2016). The effects of heat adaptation on physiology, perception and exercise performance in the heat: A meta-analysis. *Sports Medicine*, *46*(11), 1699-1724.

Vargas, N. T., Chapman, C. L., Sackett, J. R., Johnson, B. D., Gathercole, R., & Schlader, Z. J. (2019). Thermal Behavior Differs between Males and Females during Exercise and Recovery. *Medicine & Science in Sports & Exercise*, *51*(1), 141-152.

Waldron, M., Jeffries, O., Tallent, J., Patterson, S., & Nevola, V. (2019). The time course of adaptations in thermoneutral maximal oxygen consumption following heat acclimation. *European Journal of Applied Physiology*, *119*(10), 2391-2399.

Watt, M. J., Howlett, K. F., Febbraio, M. A., Spriet, L. L., & Hargreaves, M. (2001). Adrenaline increases skeletal muscle glycogenolysis, pyruvate dehydrogenase activation and carbohydrate oxidation during moderate exercise in humans. *The Journal of Physiology*, *534*(1), 269-278.

Weinman, K. P., Slabochova, Z., Bernauer, E. M., Morimoto, T., & Sargent, F. (1967). Reactions of men and women to repeated exposure to humid heat. *Journal of Applied Physiology*, *22*(3), 533-538.

Wendt, D., van Loon, L. J., & Lichtenbelt, W. D. M. (2007). Thermoregulation during exercise in the heat. *Sports Medicine*, *37*(8), 669-682.

Westaway, K., Frank, O., Husband, A., McClure, A., Shute, R., Edwards, S., Curtis, J. & Rowett, D. (2015). Medicines can affect thermoregulation and accentuate the risk of dehydration and heat-related illness during hot weather. *Journal of Clinical Pharmacy and Therapeutics*, *40*(4), 363-367.

Willmott, A. G., Hayes, M., Waldock, K. A., Relf, R. L., Watkins, E. R., James, C. A., Gibson, O.R., Smeeton, N.J., Richardson, A.J., Watt, P.W. & Maxwell, N. S. (2017). Short-term heat acclimation prior to a multi-day desert ultra-marathon improves physiological and psychological responses without compromising immune status. *Journal of Sports Sciences*, *35*(22), 2249-2256.

Willmott, A. G., Hayes, M., James, C. A., Dekerle, J., Gibson, O. R., & Maxwell, N. S. (2018). Once□and twice□daily heat acclimation confer similar heat adaptations, inflammatory responses and exercise tolerance improvements. *Physiological Reports*, *6*(24), e13936.

Willmott, A. G., Hayes, M., James, C. A., Gibson, O. R., & Maxwell, N. S. (2020). Heat acclimation attenuates the increased sensations of fatigue reported during acute exercise-heat stress. *Temperature*, *7*(2), 178-190.

Wingfield, G. L., Gale, R., Minett, G. M., Marino, F. E., & Skein, M. (2016). The effect of high versus low intensity heat acclimation on performance and neuromuscular responses. *Journal of Thermal Biology*, *58*, 50-59.

Yoshida, T., Shin-ya, H., Nakai, S., Yorimoto, A., Morimoto, T., Suyama, T., & Sakurai, M. (2006). Genomic and non-genomic effects of aldosterone on the individual variation of the sweat Na+ concentration during exercise in trained athletes. *European Journal of Applied Physiology*, *98*(5), 466-471.

Yanovich, R., Ketko, I., & Charkoudian, N. (2020). Sex differences in human thermoregulation: relevance for 2020 and beyond. *Physiology*, *35*(3), 177-184.

Young, A. J., Sawka, M. N., Levine, L., Cadarette, B. S., & Pandolf, K. B. (1985). Skeletal muscle metabolism during exercise is influenced by heat acclimation. *Journal of Applied Physiology*, *59*(6), 1929-1935.