Knowledge and Strategies of Heat Acclimation and Heat Acclimatization in Elite Runners

by

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ABSTRACT

Events such as the Summer Olympic Games and the World Athletic Championships are held each year in hot and humid conditions. Heat stress negatively affects endurance performance and imposes safety concerns for elite runners. The purpose of this dissertation was to highlight heat acclimation (HA) and heat acclimatization (HAz) knowledge and strategies in elite middle- and long-distance runners from Kenya and the United States (US). In the first study, elite runners were surveyed on their HA and HAz knowledge and their history of exertional heat illness (EHI). In the second study, strategies of both HA and HAz and how the runners perceived their effectiveness were investigated. Participants (N =30) were recruited through an email sent directly to the elite runners or coaches and completed an online survey. Knowledge scores were similar for Kenya (M = 50.0, SD = 15.1) and US (M = 57.6, SD = 16.5) runners (mean difference = -7.53, 95% CL [-20.23, 5.16]). The were no significant differences in HA and HAz strategies used ($p > .05$). Perceptions of effectiveness were similar for the Kenya ($M = 6.7, SD = 1.9$) and US ($M = 8.0, SD = 1.5$) runners (mean difference = -1.26, 95% CL [-2.60, 0.08]). Overall, there were no significant differences between the US and the Kenya elite middle-and long-distance runners in respect to the level of HA and HAz knowledge, reported history and symptoms of EHI, choice of HA and HAz strategies, and how their perceived effectiveness. Coaches and professionals in charge of elite runners should continue to develop comprehensive guidelines and education initiatives on combating heat stress. Universal HA and HAz protocols that adequately prepare elite runners for competitions hot and humid conditions are encouraged.

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CHAPTER I

DISSERTATION INTRODUCTION

The human body functions most efficiently in the temperature range of 35-40°C. Any increase in body temperature beyond the normal range presents threats to homeostasis and negatively impacts the endurance performance of elite runners (Parsons, 1993). Several major distance running events are held each year in hot environments, including the Summer Olympic Games and the World Championships. The 2020 Tokyo Olympics was not an exception. It was hot and humid in Japan. The Japanese Environmental Agency reported the wet bulb globe temperature (WBGT), a heat index measure combining heat and humidity used by organizers to assess safety, hit 31.8°C (British Broadcasting Corporation [BBC], 2021). The hot and humid conditions imposed physiological challenges on the elite runners and impacted athlete's maximum endurance performance (Gerret et al., 2019). The race organizers implemented safety precautions and offered different cooling interventions to mitigate the heat stress. Some long-distance events, such as the marathon, were scheduled at a different location and started at midnight.

Race organizers and the Olympic committee use weather variables such as radiation, wind speed, ambient temperature, and humidity when determining whether it is safe for an event to be held. A WBGT reading greater than 28°C calls for the postponement of the event because the heat stress is critical and indicates high-risk for the runners (Cheung, 2010; Tokyo Sports Association, 2013). Hot and humid conditions (35°C, 60% RH) expose elite middle- and long-distance runners to exertional heat illness (EHI), this includes muscle cramps, heat exhaustion, or extreme heat illness such as heat stroke.

While heat acclimatization is important for optimal health and performance, most elite middle- and long-distance runners do not heat acclimatize before competing in a hot and humid environment. For example, Gibson et al. (2019) surveyed athletes competing during the 2015 International Athletic Association Federation (IAAF) World Athletics Championships in Beijing, China, and reported only 15% had adopted heat alleviation strategies prior to the competition. While trained athletes have partial adaptation to heat stress (for example increased sweat rates and earlier onset of sweating), it is important that they be fully heat acclimated (HA)/acclimatized (HAz), before competitions in hot and humid environments to avoid performance decrements.

Repeated exposure to hot and humid environments promotes physiological adaptations (Sawka et al., 2011) beneficial to endurance performance. Prior to competition, elite runners can expose themselves to similar conditions through artificial heat stress like the use of heat chambers, hot water immersion (HWI), sauna bathing, or over-dressing. Athletes can also train in the actual natural environment with extreme heat to impose adaptations. Physiological adaptations to the heat stimulus occur within 4-5 days of training, but maximum benefits require 10-14 days (Benjamin et al,.2021; Periad et al.,2015; Racinais et al., 2015b; Tyler et al., 2016). Heat acclimation results in adaptations which promote cardiovascular stability, improved thermoregulation responses, decreased physiological strain, and increased capacity for heat tolerance in hot and humid conditions. Some of the adaptations post-HA include increased sweat rate, reduced core and skin temperature, expansion in plasma volume (PV), and increased regulation of heat shock proteins which protect cells from extreme heat (Casadio et al., 2016; Herowitz et al.,2002).

The fundamental requisite for effective HA involves substantial and repeated increases in core temperature, skin temperature, and sweating (Casidio et al.,2016; Gipson et al.,2015). The magnitude of physiological adaptations is dependent on the duration, frequency, intensity, and type of heat exposure protocols. Beneficially, once an athlete is acclimated to the heat, the rate of decay of the adaptations can be prolonged by including heat exposures post HA/HAz. Also, re-acclimation following a dedicated period of HA is accelerated compared with the initial rate of acclimation (Weller et al., 2007). Thus, conducting an initial heat acclimatization camp several weeks before the target event may increase the speed at which adaptations occur in a follow-up pre-competition camp.

While training athletes in the natural environment they are going to compete in is the best HA technique (Casadio, 2016; Macon, 2022), this may not be practical for all elite middle- and long-distance runners due to the socio-economic status of runners which may lead to limited monetary resources to travel to competition venues. Therefore, it is important to consider alternative forms of HA which include passive HA methods such as sauna bathing and HWI, or more active HAz techniques such as use of a heat chamber and excess clothing. Whichever method is selected, it is important that an athlete understands the need for, and benefits associated with, preparing to compete in hot and humid environments. At an elite level of competition, it is critical, training quality can be maintained, and performance can be maximized in hot and humid environments.

Purpose of the Study

The overall purpose of this dissertation is to highlight the HA/HAz knowledge and strategies used by elite middle-and long-distance runners in the United States and Kenya. In the first study, athletes will be surveyed on their HA knowledge and their history of heat illness. In the second study, the strategies used for HA/HAz and their perceived effectiveness will be determined and compared between runners in the United States and runners in Kenya.

Significance of the Study

Elite middle- and long-distance runners expend significant resources and physical effort to prepare for peak performances at world athletic and Olympic championships. It is evident that HA/HAz can exponentially enhance physiological and perceptual adaptations (Casidio et al.,2016; Sawka et al.,2011) and improve endurance running performance. Although many HA protocols have been proposed, no consensus has been made on 'optimum' approaches, especially in developing countries like Kenya, where there are less resources. Few studies have investigated the impact of HA/HAz on elite middle-and long-distance runners from different regions with varying weather seasons, also considering different social economic status (Benjamin et al., 2021).

Assessing knowledge of HA/HAz and history of EHI during competitions in hot and humid environments will aide in determining awareness and if educational programs are needed to increase knowledge of elite athletes who will potentially be exposed to these conditions. Understanding the HA/HAz strategies used by the elite middle- and long-distance runners from Kenya and the US can help to facilitate proper guidelines on more effective protocols among athletes with different environmental training conditions.

CHAPTER II

REVIEW OF LITERATURE

Introduction

In 2021, athletes competed in the Tokyo Summer Olympics in hot and humid conditions (35°C, 60% RH). The Japanese Environmental Agency reported the WBGT, a heat index measure combining heat and humidity, used by organizers to assess safety, hit 31.8°C (British Broadcasting Corporation BBC, 2021). These conditions exposed athletes to conditions impairing optimal performances (Gerret et. al., 2019). Today, WBGT is the most widely used index of heat stress and heat illness (Budd, 2008). Elevated temperatures not only impose health issues on athletes due to EHI, but also impair endurance performance of middle- and long-distance runners. Heat-induced performance decrements range from 6% to 16% in trained athletes during endurance and team sports events, while lack of acclimation is a major risk factor for EHI (Casadio et al., 2017). Forecasted weather trends indicate it is likely the Olympic Games and World Athletic Championships running events will be scheduled during periods of increasingly hot and humid conditions. Therefore, it is critical for elite runners, coaches, and trainers to understand techniques of HA and HAz to mitigate the negative impact of heat stress. Gipson et al. (2020) highlighted in their review that it is essential for middle- and long-distance runners to use HA strategies to attenuate heat strain during competition in hot and humid environments.

The first section of this literature review is a description of the acute physiological responses to running in a hot and humid environment, which include changes in the cardiovascular system, stimulation of sweat and related dehydration, and heat stress that can impair running performance. The second section highlights physiological responses to running in elevated heat and a review of physiological adaptations after HA, which includes thermoregulation responses including adjustments in the cardiovascular system and metabolic adaptations. The third section of this review explores HA techniques and protocols used by elite middle- and long-distance runners to maximize endurance performance during competitions in hot and humid environments. The review of the literature ends with an overall summary.

Physiological Responses While Running in Hot and Humid Environments

The human body attempts to maintain a constant core temperature of 37°C across a wide range of ambient temperatures (55°C - 25°C). Generally, efficient thermoregulation occurs across a core temperature range of 35°C to 40°C (Parsons, 1993). During high intensity endurance training or competition in hot and humid conditions, the combined circulatory demands of skeletal muscle and skin can significantly impair oxygen transport capacity. Consequently, exercise capacity and the body's ability to dissipate heat and maintain blood flow to the working skeletal muscles is negatively affected (Ely et al., 2018). Running in hot and humid environments exacerbates physiological strain and challenges body temperature homeostasis. Thus, hot conditions induce elevated body temperature and cardiovascular strain, and affect sweat rate response, dehydration, and metabolism. These effects can cause thermal discomfort, impaired aerobic performance, and increased risk of EHI (Nybo et al., 2014; Periad et al., 2016; Sawka et al., 2011). With variation across sex, running distance, level of fitness, and whether the athlete is heat acclimatized, the ideal ambient environmental temperature for the fastest times in middle- and long-distance events is between 10.6 °C – 13.6 °C (Powers et al., 2018). Temperatures above this range result in slower running times. The physiological responses to exercise in hot and humid conditions are highlighted in the following section.

Cardiovascular Responses

When competing in a high heat environment, the body acutely increases skin blood flow. The superficial arterial and venous blood vessels dilate to divert warm blood to the skin. This manifests as a flushed face on a hot day or during exercise. With extreme heat stress, 15-25% of cardiac output (Q) passes from the core to the skin. Rowel (1986) highlighted in his investigation that during exercise in the heat, thermoregulatory skin flow may be as high as 7 L/minute. The enhanced cutaneous blood flow increases the thermal conductance of peripheral tissues (McArdle et al., 2008). However, when training and competing in temperatures of 40°C or above, there is competition between the thermoregulatory demands to increase skin blood flow and the metabolic demands to increase muscle blood flow (Ely et al., 2018). This heat stress causes physiological strain and affects the athletes heat tolerance and also the ability to maintain running pace. Endurance performance is further reduced by a rapid increase in core temperature and ambient temperature exceeding skin temperatures, or sweat evaporation decreasing due to high water vapor.

Muscles require delivery of oxygenated blood to sustain aerobic energy metabolism. Sawka et al. (1988) stated when heat stress is combined with exercise, the cardiovascular system may be limited in supporting the competing metabolic and thermoregulatory demands resulting in cardiac strain. When this occurs, there is a decrease in Q and stroke volume (SV). Rowel et al. (1966) reported that running in the heat reduces Q by 1.2 L/minute which could account for a 0.25 L/minute decrement in aerobic capacity ($VO_{2\ max}$). To maintain Q, the cardiovascular system increases heart rate (HR; Sawka et al., 1993). Dehydration in hot and humid conditions can compound this response by decreasing total blood volume.

The magnitude of heat stress response not only causes cardiovascular consequences but also has negative impacts on neuromuscular activity. Nybo et al. (2001) investigated 14 men exercising at 60% maximal oxygen consumption on a cycle ergometer in hot (40°C; hyperthermia) and thermoneutral (18°C; control) environments. Core temperatures increased throughout the exercise in both groups of participants, but muscle activity declined significantly in a hot environment at a faster rate than in a cool environment. In another study, Tucker et al. (2004) had participants perform a self-paced 20-kilometer cycling time trial in cool (15°C) and hot (35°C) environments. The participants in the hot condition displayed significantly lower muscle activity and power output, beginning as early as 30% into the time-trial (Tucker et al., 2004). Together Tucker et al. (2004) and Nybo et al. (2001) demonstrated that exercising in hot conditions affects recruitment of motor unit activity by the central nervous system (CNS). A similar study on goats showed a decrease in running speed when the hypothalamic temperature was independently increased to ~43°C, supporting the idea that motor activity is inhibited by high temperatures in the CNS (Nybo et al., 2001).

It is evident that running in a hot and humid environment causes cardiovascular system strain and suppression of the CNS. Thus, heat stress impacts endurance performance of middle- and long-distance runners. During competition, the rivalry between skin and muscle blood flow affects the athlete's running pace and heat tolerance. The cardiovascular system responds to heat stress by maintaining Q with the support of proper physiological Response of HR and SV. The increased sweat rate response while exercising in hot and humid conditions can also negatively impact performance.

Sweat Rate Response

Exercising in a hot and humid environment also increases sweat rate. The eccrine glands are stimulated to secret sweat when the ambient temperature is greater than the skin temperature. Although increased sweating is important for thermoregulation through evaporation, concerns arise when fluid loss causes a decrease in plasma volume (PV). This decrease in PV makes the blood viscous effecting blood flow and oxygen delivery to the skeletal muscles. The rise in blood viscosity caused by red blood cell deformity may increase vascular resistance and cardiovascular strain (Robert et al., 2020). This decrease in PV results in dehydration and reduces aerobic performance. Earlier studies by Rowel and colleagues (1974) highlighted an increased sweat rate and decreased PV, which ultimately reduced SV. The resulting dehydration may lead to HR compensation through cardiovascular drift. The increased HR is an effort to maintain Q. If the elite athlete keeps a high pace in a hot environment, the increase in HR will not be sufficient to maintain Q. Therefore, decreased HR and SV ultimately decrease Q, thus impairing performance.

An imbalance in the body's PV and lost sodium in sweat may also cause heat cramps (Cheung, 2010). A heat cramp is related to a deficiency in the body's electrolytes such as sodium chloride (NaCl). Sawka et al. (2011) stated that daily water and sodium losses of 4 -10 L and 3,500-7,00 mg, respectively, in active athletes during hot weather exposure can induce water and electrolyte deficits. Sawka et al. (2011) found when a person enters a hot environment, they start sweating because of an increase in skin temperature before any rise in core temperature. To prevent heat illness, blood is shunted closer to the skin and away from the core and skeletal muscles to dissipate body heat via convective currents and evaporation at the periphery. As the volume of blood is transported from the core to the skin surface, the capacity for oxygen transportation to the working muscles decreases, which is detrimental to endurance performance (Rowell, 1974). The body's cooling mechanism of evaporation thereby becomes ineffective when exercising in a humid environment.

An average person sweats between 0.8 to 1.4 liters per hour during exercise in the heat. In comparison, Wendt et al. (2007) noted elite athletes performing high-intensity exercise in the heat, commonly have sweat rates of 1.0 - 2.5 L/hour, and during hot and humid condition (35°C, 60% RH), their sweat rates can rise to > 2.5 L/hour. The highest sweat rate reported in the literature is 3.7L/hour, measured for Alberto Salazar during the 1984 Olympic Marathon (Amstrong et al., 1986). Although the enhanced sweat rate and volume provide a physiological advantage when running in hot and humid conditions, the consequences of excessive sweating on physiology and the resulting decrement in performance may be greater in these individuals. The physiological strain caused by the increased sweat rate and the inability of the body to properly compensate for lost body fluids inhibits the thermoregulatory responses while running in hot and humid conditions.

Overall, the acute physiological responses while running in hot and humid conditions can result in performance decrements and increased risk of EHI. There is competition between skin and muscle blood flow and a decrease in PV due to excessive sweating can cause loss of important electrolytes and increase blood viscosity. To combat the negative consequences of these responses on health and performance, runners must acclimatize before competing in hot and humid environments.

Physiological Adaptations to Heat Stress

Gibson et al. (2019) surveyed athletes competing during the 2015 International Athletic Association Federation (IAAF) World Athletics Championships in Beijing, China, and reported only 15% had adopted heat alleviation strategies prior to the competition. While trained athletes have partial adaptation to heat stress (for example increased sweat rates-and earlier onset of sweating), it is important they be fully heat acclimatized before competitions in hot and humid environments.

The mean daily temperature and WBGT during the 2015 IAAF World Athletics Championships were 27 ± 3°C and 24 ± 2°C at 8:00 am, 31 ± 3°C and 27 ± 2°C at 12:00 pm, and 30 ± 4°C and 25 ± 2°C at 4:00 pm (Gibson et al., 2019). Temperatures in this range were detrimental to athletes' health and affected the performance of most middle-and long-distance runners, ranging from distances of 800 m to the marathon. When WBGT temperatures are above 28°C (82°F) it is recommended that races be postponed as this is considered very high risk of EHI. The high-risk temperatures range is 23 to 28°C (73 - 82°F). Based on the Japan Sports Association (2013) WBGT guidelines, athletes who are unacclimatized and with previous history of EHI should not compete at very high-risk and high-risk temperatures. Acceptable temperatures for competition for all athletes include the moderate risk range of 18 - 23 °C (65 - 73°F) and the low-risk temperature of below 18 degrees (< 65°F).

The best competition temperature range for middle- and long-distance runners is between 10 and 13°C (Minson, 2022). To maximize performance and attenuate heat stress illness during competitions, elite runners can be exposed to similar conditions using HA (through artificial heat stress like the use of heat chambers, hot water immersion, sauna, or over-dressing) or HAz (such as training in the actual natural environment with extreme heat) to impose adaptations. Most adaptations occur within 4-5 days of training, 60 – 90 minutes per day, at moderate intensity, but maximum benefits require 10-14 days. Heat acclimation results in physiological adaptations which promote cardiovascular adaptations, thermoregulatory responses, and metabolic adaptation to HA (Tyler et al., 2016).

Cardiovascular Adaptations

Physiological adaptations to heat stress improve cardiovascular function and aerobic capacity in hot and humid conditions. The heat generated because of the mechanical work while running and the heat stress from the external environment cause increased blood flow from the core to the skin surface, to allow loss of heat through evaporation. The higher skin blood flow necessitates an increased Q. The increased workload on the heart in pumping blood is a major source of cardiovascular strain associated with heat stress. As skin blood flow increases to decrease the internal heat load, the blood vessels of the skin become engorged as large volumes of blood pool in the skin to allow efficient thermoregulation and cardiac stability. Cardiac stability is attained when there is fluid balance, decreased exercising metabolic rate, and expansion of plasma volume (PV).

Heat acclimation promotes adjustments in blood circulation and evaporative cooling which enables heat-acclimatized elite middle- and long-distance runners to run with lower skin and core temperatures and HR. Johnson (2010) highlighted a lower exercise core temperature requires the diversion of less blood to the skin, thus freeing a larger percentage of the Q for active muscles. Therefore, the competition between thermoregulatory control of body temperature and the metabolic demand of running is lessened following HA. Further, HA enables stabilization of blood pressure during exercise in hot and humid conditions.

Following HA, there is improved blood distribution to the skin and skeletal muscles due to earlier peripheral vasodilation. Vasodilation occurs because of thermoreceptors that detect the change in body temperature which results in an earlier onset of sweating and reduced electrolytes imbalance. Electrolyte stability results in cardiac stabilization. For example, heat acclimated individuals have more efficient compensatory mechanisms that constrict splanchnic vascular beds and renal tissues. This rapidly counteracts active vasodilation of the subcutaneous vessels which are responsible for 80 – 95% of elevated skin blood flow (McArdle et al., 2010). The balance between vasodilation and vasoconstriction while running in a hot and humid environment will maintain arterial blood pressure thus promoting cardiovascular efficiency. These mechanisms further improve thermoregulation to meet metabolic demand during competitions in hot and humid conditions. Cardiovascular adjustments due to heat stress also impacts PV.

Changes in PV

Cardiovascular strain is exacerbated in hot and humid conditions by the loss of PV due to an increased sweat rate and dehydration (Cheung, 2010). Following HA, there is an increase in movement of fluids between plasma and skeletal muscle tissues. The increase in total body water is due to the preservation of sodium, which increases extracellular fluid. The osmolality of PV increases due to improved reabsorption of NaCl. These extracellular fluid movements occur quickly, before any substantial loss of fluid occurs by sweating (Sawka et al., 2008). The overall magnitude and direction of extracellular fluid volume depend on factors such as temperature, hydration level, and status of HA. Early studies by Lorenzo et al. (2010) and King et al. (1985) found that short term HA for 8-10 days increase PV by approximately 6.5% and 9.2%, respectively.

Different reasons account for increased PV. One reason is increased reabsorption or retention of NaCl. Because the main solute in sweat is NaCl, the water in the sweat will be lost disproportionately at the expense of extracellular fluid to the extent that the body's content of sodium ions is depleted (Sawka et al., 2008). Consequently, heat acclimatized distance runners have reduced sodium loss from the kidneys. The increased NaCl retention and reabsorption will contribute to increases in PV. The adjustment in evaporative cooling and thermoregulation will facilitate running at a faster pace with lower core and skin temperatures. A lower core temperature will divert less blood flow to the skin surface and improve Q distribution to the active muscles. Secondly, hormonal changes play a key role in the increase in PV in response to heat stress as a physiological adaptation. A vital hormone is antidiuretic hormone, also known as vasopressin (Périard et al., 2015). In response to heat stress, the blood vessels in the skin become dilated which results in a decrease in blood pressure. With low blood pressure, the pituitary gland is stimulated to produce vasopressin which helps in the retention of fluid in the body, resulting in decreased urine output. These hormonal changes result in an increase in PV which aids in restoring blood pressure to the normal physiological value. In addition, the adrenal glands produce aldosterone, a hormone, which regulates plasma volume during heat stress (Périard et al., 2015). Lastly, Gillen et al. (1991) also highlighted that albumin proteins are enhanced after HA thus increasing movement of fluids from interstitial spaces to circulation blood vessels. Heat acclimation promotes physiological adaptations that reduce cardiovascular strain. The greater expansion of PV is due to NaCl retention, hormonal changes, and enhancement in albumin proteins post-HA. These changes are thought to improve Q and hence cardiovascular efficiency (Périard et al., 2015). In the next section, thermoregulatory responses after HA are highlighted. The thermoregulation mechanisms discussed include responses of sweat rate, and changes in skin and core temperatures.

Thermoregulatory Responses

Thermoregulation is achieved in the body by balancing heat stored and heat dissipated. Heat can be produced by the body through metabolism or physical work. Nevertheless, body heat production is exacerbated by running in hot and humid conditions. Negative implications such as heat exhaustion, heat cramps or syncope occur when heat storage exceeds heat dissipation. Heat produced by the body can be dissipated through radiation (R), convection (C), conduction (K), and evaporation (E). The body's heat storage is described by the heat balance equation, heat storage (S) = Metabolic work (M) +/- work rate (W) +/- R +/- C +/- K – E (Cheung, 2010; Sekiguchi et al.,2022). Evaporation is the major physiological defense against overheating during exercise. The body is capable of dissipating 30-100% of metabolic heat through evaporation (Sekiguchi et al,.2022). However, an increase in environmental temperature and high humidity interferes with the body 's mechanism of sweating, hence compromising the cooling ability of the body via sweat evaporation. Through HA and HAz the body adapts by lowering HR, core temperature, skin temperature and increasing blood flow to the skin surface (Sekiguchi et al,.2022). Once these thermoregulatory responses are sufficient to dissipate heat at the rate at which it is being produced, thermal balance and core temperature are restored.

Other positive effects of HA include earlier onset of sweating, increased sweat rate, and sweating more dilute sweat to conserve electrolytes. The body contains two to four million sweat glands. During heat stress, these sweat (eccrine) glands (which are controlled by cholinergic sympathetic fibers) secrete high amounts of very dilute (hypotonic) saline solution (0.2 to 0.4% NaCl; Cheung, 2010). Regular training by runners has been shown to enhance sweat production by eliciting changes in the sensitivity of eccrine glands, total sweat output, and distribution of gland activity. Also, HA produces similar changes, and results in reduced sweat thresholds (Taylor 1986). In addition, Sawka et al. (2011) highlighted that thermoregulatory adaptation through HA includes early onset of diluted sweating with reduced loss of sodium and an increased sweat rate which translates to improved heat dissipation through evaporation. These improved sweating responses help elite middle- and long-distance runners better tolerate hot and humid running conditions. Earlier studies by Nedal et al. (1974) and more recent studies by Patterson et al. (2004) and Sekiguchi et al. (2022) reported an increase in sweating sensitivity due to HA within 5 to 10 days. Post HA or HAz, the central nervous system initiates and regulates the sweat response more effectively due to the increase sensitivity of the central drive for sweating. Acclimatized athletes sustain their exceptional potential for evaporative cooling only with adequate fluid replacement. Fluid replacement must maintain PV so circulation and sweating progress at optimal levels.

Running in the heat exacerbates core temperature. Periad et al. (2015) highlighted that body core temperature is typically regulated about a mean value of ∼37 °C, remaining within a narrow functional range of 35 to 41 °C. The skin thermoreceptors sense the rise in blood temperature and relay information to the anterior portion of the hypothalamus. The feedback from the hypothalamus initiates vasodilation and increased blood flow to skin which results in transfer of the heat from the core to the skin where it is excreted through sweat evaporation (Johnson, 2010; Tyler et al., 2016). Heat acclimation lowers core and skin temperatures. In hot and humid conditions, the core-to-skin gradient is less than in cool environments, so that the skin blood flow must be relatively high to achieve sufficient heat transfer to maintain effective thermoregulation (Sawka et al., 2011). Skin temperature increases accompany increased core temperature and transfer of heat to the skin via vasodilation. This mechanism promotes heat loss via sweat evaporation from the skin surface to the environment while running in a hot and humid environment. The rate of evaporation depends on air movement, wetted skin surface, and the surrounding air around the skin; the wider the gradient, the greater the rate of evaporation (Cuddy et al., 2014; Cheng et al., 2013; Lorenzo et al., 2010; Nielsen et al., 1997; Periad et al., 2015; Sawka et al., 2011).

Thermoregulation is achieved by the balance between heat stored in the body core and the heat dissipated from the body via evaporation of sweat from the skin surface. The thermoregulatory response after HA includes early sweating, increased sweat rate, more dilute sweat output, and increased thermotolerance by running at lower core and skin temperatures. In addition, to improved thermoregulation post-HA, the body also adapts metabolically by increasing heat shock proteins (HSP). Heat shock proteins are thought to protect the muscular cells from extreme heat stress.

Metabolic Adaptations to HA

Heat shock proteins are a group of stress proteins produced because of high temperatures. These proteins maintain the structure and function of proteins and protect the body’s cells from damage due to heat stress. An increase in HSP, especially intracellular HSP72 levels, has been shown to improve whole body thermotolerance by maintaining intestinal epithelial tight junction barriers, by increasing resistance to gut-associated endotoxin translocation, and by reducing inflammatory response (Amorim et al, 2015; Périard et al., 2015). Extracellular HSP 72 (eHSP72) has been found to increase acutely with elevations in core temperature, as observed during exercise in the heat, and is thought to be involved in an immune response to exercise and hyperthermia (Johnson, 2010). Although not universally noted, acute bouts of exercise-heat stress result in transient increases in eHSP72, whereas HA resulted in increases in intracellular HSP72 and decreases in eHSP72 (Amorim et al., 2015; Sawka et al., 2015; Yamada et al., 2007). The magnitude of response appears varied, but may be related in part to fitness level, as the stressor may be less novel in well-trained individuals. Sawka et al. (2011) highlighted in their study that acquired thermotolerance due to increased HSP72 is associated with HSP binding to cellular polypeptides, providing protection, and accelerating repair from heat stress.

Overall, most physiological adaptations experienced by elite middle- and long-distance runners post-HA or heat acclimatization occur within 4-5 days of training, 60 – 90 minutes per day, at moderate intensity in the heat, but maximum benefits require 10-14 days (Tyler et al., 2016). Heat acclimation results in cardiovascular adaptation observed by expansion in PV, increased Q, and vasodilation. Thermoregulatory responses improve post-HA by increased dilute sweat output, sweat rate, and early onset of sweat. Heat acclimatized individuals also exercise at a lower core and skin temperature. Finally, metabolic adaptation is seen by increased HSP, which protects the cell from extreme heat stress. The review of literature has established evidence that HA is impactful in physiological and perceptual adaptations, It is therefore important to review HA techniques used by elite middle- and long-distance runners to prepare for competitions in hot and humid environments.

Strategies used for HA and HAz

Repeated exposure to hot and humid environment promotes physiological adaptations (Sawka et al., 2011). Although, elite runners are partially HA due to training, incorporating HA techniques before competing in hot and humid conditions is important to maximize endurance performance and mitigate the probabilities of suffering EHI. The magnitude of physiological adaptations is dependent on the duration, frequency, intensity, and type of varied heat exposure protocols. International competitions such as the summer Olympic and world athletic championships are likely to occur during the hot and humid months. Past data show that elite athletes experienced significant heat stress which impaired endurance performance and exposed the athletes to EHI.

The HA techniques should properly align with the timing before competition in hot and humid conditions. The frequency, intensity, and durations should also consider the training periodization. Most of the HA regiments are done during the tapering period or before travel. The fundamental requisite for an effective protocol involves substantial and repeated increases in core temperature, skin temperature, and sweating. Also, the relative success of a heat adaptation program depends on the specificity (active vs. passive) and frequency of the exposure. It is ideal that at least 60–90 min of exercise is undertaken in the heat to confer rapid adaptations (Tyler et al., 2016), and a total period of 2 weeks is allocated to facilitate maximal adaptations (Racinais et al., 2015b). The rate of decay can be prolonged by including heat exposures post-HA/HAz. Importantly, re-acclimation following a dedicated period of heat acclimation is more accelerated compared with the initial rate of acclimation (Weller et al., 2007). Thus, conducting an initial heat acclimatization camp several weeks before the target event may increase the speed at which adaptations occur in a follow-up pre-competition camp. For example, the main acclimatization block can be performed in the 2 weeks before travel, with 4–5 days of re-acclimation after arrival at the competition venue. Such planning accounts for the tapering the athlete needs before a major competition (Daanen et al., 2018). Thus, it may be more feasible if an acclimatization block was to be undertaken a few weeks before, followed by acute heat exposure throughout the taper to maintain the initially conferred adaptations.

Training athletes in the natural environment that they are going to compete in is the preferred HA technique (Macon, 2020). However, it is not practical for all elite middle- and long-distance runners due to accessibility and the monetary resources to travel to those areas. Therefore, it is important to consider alternative forms of heat acclimation techniques which include active HA/HAz techniques such as training with excess clothing and use of heat chamber, or alternatively, utilizing passive HA methods such as sauna bathing and hot water immersion (HWI).

Elite middle- and long-distance runners are known to follow a strict periodized training program and HA/HAz regimens should be well planned in order not to interfere with the athletes' training program. Therefore, coaches and elite runners should choose the most cost effective and less training interruptive strategy. In the next section, HA/HAz strategies will be presented as either active or passive. Active HA/HAz include natural environment, heat chamber, and excess clothing while the passive strategies include sauna bathing and HWI.

Active HA/HAz Strategies

Heat acclimatization typically occurs in a natural environment in a location where training activities may combine with mean daytime temperatures to provide sufficient stimuli (elevated core, skin, and high sweat rates) for adaptation. This allows elite runners to live and, most importantly, train in heat stress for extended periods of time (e.g., 1–4 weeks) before competing in hot and humid conditions. Macon (2020) reported that the use of acclimatization to the natural environment was the most common heat exposure technique used by the collegiate coaches in the United States during a HA program, with 73.7% of the total sample responding they used this technique. The author reported use of this strategy was associated with the geographic location of participants where coaches at schools in the southern United States utilized the natural environment most readily (Macon, 2020). When training in the natural environment athletes can control the duration of exposure and train in conditions that will match those during competition. A challenge with this technique is the cost of travel, especially by the athletes who live in more temperate or cold environments. Another active strategy of HA that can be used, although not feasible or cost friendly, is the use of a heat chamber.

Athletes repeatedly exercise in a heat chamber as part of an active intervention. There are varying protocols that can be modified to suit different athletes. Typically, most protocols range from 9–15 days in duration to elicit physiological adaptations. In addition to training in a heat chamber, some protocols include the use of vapor impermeable suits or blankets to reduce sweat evaporation, heat loss, and/or promote the achievement of a target core temperature (Kanikowska et al., 2012). The enhanced sweat rate responses following acclimation protocols have also occurred at rest upon exposure to heat. However, no significant changes in plasma sodium, potassium, total protein, and albumin levels were noted after a heat chamber involving rest for 4 h at 46°C and 20% relative humidity (Shido et al., 1999). A heat chamber offers a practical intervention for HA/HAz because athletes can run at similar intensities on a motorized treadmill just like an outdoor workout. Another practical active intervention that is feasible and less costly is use of excess clothing for HA.

The use of excess clothing as a heat exposure method is still an understudied topic. Recently researchers suggested excess clothing in a temperate environment can introduce the requisite heat strain to induce HA, though it may not be as effective as exercise in high heat (Ely et al., 2018). While exercise in excess clothing can increase core temperature, excess clothing elicits a lower skin temperature and HR than exercise in just high heat conditions (Willmott et al., 2018). Excess clothing may provide a stimulus to induce some thermoregulatory adaptations, however, further research into the use of excess clothing should investigate whether this method provides robust adaptations that improve athletic performance.

When utilizing excess clothing to generate heat exposure, parts of the skin surface (face, hands, head, etc.) may still be exposed to the natural environment, allowing for effective sweat evaporation, and reducing the overall heat stimulus. To clarify the effectiveness of this strategy, research investigating the magnitude of HA generated from the use of excess clothing should be evaluated at various levels of body coverage. Heat stimulus could also be evaluated through a variety of different levels of clothing insulation as measured by thermal insulation of clothes (CLO units), a unit of measurement that quantifies the thermal 40 insulator capacity of clothing. Research on this topic would be particularly prudent due to the functionality and widespread use of this method of heat exposure (Willmott et al., 2018). Active heat acclimation and acclimatization strategies can be effective modes of eliciting a stimulus to cause physiological adaptation before competing in a hot and humid environment. In addition to active modes of HA/HAz, passive HA/HAz is becoming more popular among individuals who want to be heat acclimatized before running in a hot and humid conditions. They use passive HA strategies such as sauna bathing and HWI.

Passive HA/HAz Strategies

Post-exercise sauna bathing represents an alternative practical means of implementing HA in elite middle- and long-distance runners when barriers to traditional exercise-based HA are present. Use of a sauna has been shown to elicit the desired physiological adaptations while overcoming travel barriers. Scoon et al. (2007) highlighted that thermal load (80–100°C, 10–20% RH) imposed by sauna bathing is a practical HA approach while Casadio et al. (2017) noted in their study that sauna bathing in a rested state impose considerable heat stress, resulting in increased core and skin temperature, sweat rate, and HR. Consecutive days of post-exercise sauna bathing in healthy untrained men has been shown to increase heat tolerance after only 3 days of exposure, as evidenced by reductions in core temperature (Casadio et al., 2017). Sauna exposure immediately following a training session may enhance the thermoregulatory-adaptive response, as core temperature, considered a key contributor to HA-induced adaptations, has been shown to rise to a greater extent compared with sauna bathing without exercise (Casadio et al., 2017). Furthermore, post-exercise heat stress may additively enhance endurance training-induced mitochondrial function through increased citrate synthase enzyme activity (Casadio et al., 2017).

Hot water immersion (HWI) is a passive form of HA. This strategy is more feasible and effective so long as the athlete has access to hot water and a "bath." The ergogenic benefits of this technique are facilitated by hematological adaptation. Hot water immersion should be undertaken at water temperatures of 40°C - 44°C for a duration of 30– 40 minutes to induce adaptation while remaining tolerable. Casadio et al. (2017) highlighted that seven 45 – min hot water baths (44°C) completed over a two-week period was shown to reduce cardiovascular strain and thermal effects (Casadio et al., 2017; Scoon et al., 2007). This approach takes advantage of core temperature being elevated after training or elevated temperatures before training. This technique of passive HA can be further combined with extra (i.e., insulative) clothing during training to increase the stimulus. Although passive HA strategies are not as specific as active HA per se, both sauna bathing and HWI can be used as alternative strategies to induce physiological adaptation and thermotolerance before racing in hot and humid environments.

Overall, elite middle- and long-distance runners can use both active and passive strategies to prepare for competitions in hot and humid environments. Active interventions of heat acclimation include exposing athletes to heat stress in a natural environment, using a heat chamber, or wearing excess clothing. Passive HA protocols include bathing sauna and HWI. Studies have shown that these strategies can be effective if proper protocols are put in place. Practitioners should consider frequency, duration, intensity, and the timing of these interventions before competing in a hot and humid environment. The ease of implementation, access, and cost, and required duration of each technique must be considered when determining the best strategy for each athlete.

Overall Summary

Heat stress negatively affects elite middle- and long- distance runners. Historically, competitions such as World Athletics Championships or summer Olympics are held during hot and humid conditions. The heat stress is unfavorable to the elite runners' endurance performance, and additionally impose EHI such as cramps, heat exhaustion or even a severe ailment like heat stroke. Unacclimatized runners are more likely to suffer from physiological strain due to heat stress than acclimatized runners.

Repeated heat stress initiates thermoregulatory adjustment that improves exercise capacity and reduces discomfort of heat exposure. The HA techniques used should properly align with the timing of competition in hot and humid conditions. Techniques commonly used are the natural environment, heat chambers, excess clothing, sauna bathing, and HWI. While the benefits of these techniques are substantial, not all athletes incorporate HA into their training programs. It is not known if this is due to lack of knowledge or lack of resources. Therefore, the overall purpose of this dissertation is to highlight the HA/HAz knowledge and strategies used by elite middle-and long-distance runners in Kenya and the United States.

CHAPTER III

KNOWLEDGE OF HEAT ACCLIMATION, ACCLIMATIZATION, AND HISTORY OF EXERTIONAL HEAT ILLNESS IN ELITE MIDDLE- AND LONG-DISTANCE RUNNERS IN KENYA AND THE UNITED STATES

Introduction

Some of the highest-profile athletic events, including most Summer Olympic Games, the Tour de France, the FIFA World Cup, as well as several annual World Cups and World Athletic Championships are held in the summer months when temperatures are high. The high-risk temperatures range is 23 to 28°C (73 - 82°F). The 2020 Tokyo Olympics was not an exception. The Japanese Environmental Agency (2021) reported the wet bulb globe temperature (WBGT), a heat index measure combining heat and humidity used by organizers to assess safety, hit 31.8°C. A WBGT above 28°C is a major concern for the health and endurance performance of elite runners.

Heat acclimation (HA) involves repeated high heat exposure to promote physiological adaptations (Casadio et al., 2016) and mitigate occurrence of exertional heat illness (EHI) when exercising in hot and humid conditions (Casa et al., 2015; Periad et al., 2015). For elite athletes and support teams preparing for pinnacle events, executing performance to the maximum potential is of utmost importance. Although, many researchers have reported the benefits of physiological adaptations to heat including expansion of plasma volume, increased sweat rate, cardiovascular adaptations, thermotolerance, and increased endurance performance (Lorenzo et al., 2010; Periad et al., 2015, Sawka et al., 2015; Tyler et al., 2016), athlete's knowledge and adoption of HA strategies remains questionable. Gibson et al. (2019), for example, surveyed athletes competing during the 2015 International Athletic Association Federation (IAAF) World Athletics Championships in Beijing, China, and reported only 15% of elite runners had adopted heat alleviation strategies prior to the competition. It is not known if elite middle- and long-distance runners do not have adequate information on HA and heat acclimatization (HAz) or if methods were selectively not utilized.

Further, it is unknown if there is a difference in the knowledge of HA techniques of elite runners from countries with different climates. Kenyan elite runners are known for dominating middle- and long-distance events at the world athletic championships and Summer Olympics. Kenya is also a country where annual average temperatures can be as high as (85 °F, 29 °C; Encyclopedia Britannica, 2023). While it may be thought that athletes regularly exposed to heat would have adequate knowledge of practices important to safely exercising in the heat, Heatherly et al. (2023) showed this not to be the case with recreational runners. In their study, recreational runners residing in the hotter and more humid southeastern United States lacked knowledge of HA and its associated benefits compared to runners residing in cooler regions of the country.

It may also be possible that economic resources impact the implementation and practice. Not every country or organization can fund travel for all athletes. Comparing athletes from Kenya and the United States will also assist in understanding how economic resources may be related to the occurrence of heat illness and HA knowledge.

Given the increased risk of EHI and the heat-induced decrements in performance that can range from 6 to 16% in trained athletes during endurance and team sport events (Racinais et al., 2015; Sunderland et al., 2005; Tatterson et al., 2000), it is important to better understand factors associated with the use or lack of use of HA strategies. Against this backdrop, the purpose of this study was to assess the knowledge of HA among elite middle- and long-distance runners in Kenya and the United States and to determine their experiences of EHI. The specific research questions were (a) does knowledge of heat acclimation vary between elite middle- and long-distance runners from Kenya and the United States? (b) does the reported history of exertional heat illness vary between elite middle- and long-distance runners from Kenya and the United States?

Methods

Participants

The sample included elite middle- and long-distance male and female runners ($N = 30$) from Kenya ($n = 19$) and the United States ($n = 11$) with an average age of 29.4 years ($SD = 6.2$ years). There were 27 males and 3 females. The athletes specialized in running events between 800 meters and the marathon. To qualify for participation, the athletes had to run a qualifying time for national or international level competitions, in their respective events. The study was approved by the university institutional review board (see Appendix A) and the National Commission for Science, Technology, and Innovation (NACOSTI) Kenyan research review board (see Appendix B). All participants provided informed consent before beginning the online survey.

Survey

The survey questions (see Appendix C) were generated by the primary investigator and adapted from previous questionnaires (Gipson et al., 2019; Heatherly et al., 2022; Macon, 2022; Periad et al., 2017). The survey included four sections: Demographics, Knowledge of HA, history of EHI, and strategies of HA. The participants completed 11 demographic questions: Age, sex, height, body mass, race, education level, nationality, physical location, years of training and competition history, event of participation, and personal best time of the event selected. The participants then completed 11 questions on HA knowledge. Specific questions included participant's source HA information, history and past practices of HA protocols, and their knowledge regarding appropriate training frequency, duration, intensity, timing of the day, and benefits of HA. Lastly, the participants completed 5 questions on experience and history of EHI.

Prior to dissemination, survey questions were reviewed for readability and clarity by consultants and experts in elite running. The survey was administered using the Qualtrics online survey platform (Qualtrics XM, Provo, Utah, USA). The survey took approximately 10 -15 minutes to complete.

Procedures

The participants were recruited during the summer of 2023 through their respective athlete representatives at the United States Track and Field (USATF) federation or Athletic Kenya (AK), word of mouth to the elite runners in the training camps, and through coaches of elite runners from different training camps. An email (see

Appendix D and E) containing a brief introductory message and a link to the survey was sent by email directly to the elite runners or to be disseminated through coaches and federation athlete's representatives. The participants were given two weeks to complete the survey and a reminder email was sent a week after the first email.

Statistical Analysis

The mean and standard deviation are reported for the total knowledge of heat acclimation scores. Knowledge scores were calculated A Welch confidence interval was used to estimate the difference in total knowledge scores of the elite middle- and long-distance Kenyan and US runners. Frequencies and percentages for the history of EHI are presented. Fisher's exact tests were used to compare the history of EHI for Kenya and US runners. A family wise alpha of ≤ .05 was used for all analyses to determine significance. All statistical procedures were completed using SAS Studio version 3.81 (SAS Institute Inc., Cary, NC).

Results

Knowledge scores were similar for Kenyan (*M* = 50.0, *SD* = 15.1) and US (*M* = 57.6, *SD* = 16.5) runners (mean difference = -7.53, 95% CL [-20.23, 5.16]). There were no significant differences between Kenya and US elite middle- and long-distance runners with respect to dehydration, hyponatremia, heat exhaustion, heatstroke, or other incidences of EHI. As well Kenya and US elite runners had similar experiences of nausea, vomiting, muscle cramps, headaches, dizziness, fainting, lightheadedness, confusion, and other symptoms of EHI. Finally, the runners from the two countries had similar rates of ending training and poor performances due to overheating (see Table 1 for details).

Table 1

Percentages for EHI History for Kenya and US Elite Runners

Variable	Kenya (n = 19)	US (n = 11)	Fisher's Exact p Value
EHI diagnosis	21.1%	0.0%	.27
Type of EHI diagnosis			
Dehydration	15.8%	0.0%	.28
Hyponatremia	0.0%	0.0%	---
Heat exhaustion	5.3%	0.0%	1.00
Heatstroke	0.0%	0.0%	---
Other incidences of EHI	0.0%	0.0%	---
Experienced symptoms of overheating in the past 12 months			
Nausea	15.8%	18.2%	1.00
Vomiting	10.5%	9.1%	1.00
Muscle cramps	26.3%	18.2%	1.00
Headache	36.8%	36.4%	1.00
Dizziness	21.1%	54.6%	.12
Fainting	15.8%	0.0%	.28
Lightheadedness	15.8%	36.4%	.37
Confusion	10.5%	18.2%	.62
Other symptoms	26.3%	9.1%	.37
End training session due to overheating	57.9%	18.2%	.06
Poor performance due to overheating	89.5%	63.6%	.16

Note. EHI = Exertional Heat Illness. US = United States.

Discussion

Looking at past running events during the World Athletic Championships or Olympic games, East Africans, specifically from Kenya, have dominated middle-and long-distance events, regardless of the temperature. Although HA and HAz practices have been studied widely, less is known on if elite runners from different geographical locations and climates possess similar knowledge and adopt similar practices of HA and HAz before travelling to compete in hot and humid environments. Against this backdrop, the purpose of this study was to assess the HA and HAz knowledge among elite middle- and long-distance runners from the US and from Kenya and to determine their history of symptoms of and occurrence of EHI.

Given the endurance performance decrements of 6 to 16% due to heath stress and EHI that have been documented in elite runners, (Racinais et al., 2015) it is important for runners to have an adequate understanding of preventative measures. There are limited data showing that elite runners who train in hotter environments, such as runners in Kenya, have superior knowledge in HA and HAz. Previously, Heatherly et al. (2023) found recreational runners residing in hotter and humid environments did not possess adequate information on HA and HAz. In the current study, knowledge scores between the US and Kenya elite runners did not differ (p >.05). As such, living and training in the hotter Kenyan environment did not result in higher knowledge of HA and Haz than runners training within the US. The elite status of the current runners may help to explain this lack of difference in knowledge scores. As elite athletes compete in events all over the world, regardless of country of origin, knowledge on how to prepare for competitions in hot and humid environments is needed by all elite athletes.

The data on the history and diagnoses of EHI among the US and the Kenyan elite runners showed no significant differences with respect to the percentage of runners who experienced dehydration, hyponatremia, heat exhaustion, heatstroke, or other incidences of EHI. As well, Kenya and US elite runners had similar experiences of nausea, vomiting, muscle cramps, headaches, dizziness, fainting, lightheadedness, confusion. There was also no difference in the percentage of runners from each country who had to end a training session or who had a poor performance due to overheating. While there were no differences, these data do highlight that within this sample of elite runners, performance was negatively impacted, and heat-related symptoms were experienced by all the athletes (except for fainting in US runners). This highlights the need for greater distribution and understanding of knowledge relative to preventative measures, the need for better implementation of preventative measures (such as delaying or moving competitions), or some combination of these.

Overall, the current data did not show evidence that residing and training in Kenya compared to the US provided an added advantage in HA and HAz knowledge and practices to elite middle- and long-distance runners. Regardless of location, runners need to focus on the occurrence of symptoms of EHI while exercising in hot and humid conditions. Elite runners are not exempted from experiencing EHI due to their cardiovascular fitness. Runners and coaches should continue to conduct HA and HAz protocols and educational initiatives that promote preventative measures of EHI. Future researchers should consider research with larger sample sizes and runners from counties other than the US and Kenya to see if results are comparable. Additionally, future research on the psychological tolerance of heat stress is warranted. While runners can be knowledgeable on how to prevent EHI they may differ on their ability to tolerate thermal discomfort during the competitions.

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APPENDIXES FOR STUDY I

APPENDIX A

IRB Approval Letter

Office of Research Compliance
2269 Middle Tennessee Blvd.
Sam H. Ingram Bldg (ING) Room 010A
Box 124
Murfreesboro, TN 37132
www.mtsu.edu/irb

Date: June 8, 2023
PI: Erick Kigen
Department: Middle Tennessee State University, Psychology, Health and Human Performance
Re: Initial - IRB-FY2023-189
Knowledge and Strategies of Heat Acclimation and Heat Acclimatization in Elite Runners

The Middle Tennessee State University Institutional Review Board has reviewed and approved by Expedited Review the above referenced research study. The approval is effective starting June 8, 2023.

Decision: Approved
Category: 7. Research on individual or group characteristics or behavior (including, but not limited to, research on perception, cognition, motivation, identity, language, communication, cultural beliefs or practices, and social behavior) or research employing survey, interview, oral history, focus group, program evaluation, human factors evaluation, or quality assurance methodologies. (NOTE: Some research in this category may be exempt from the HHS regulations for the protection of human subjects. 45 CFR 46.101(b)(2) and (b)(3). This listing refers only to research that is not exempt.)

APPENDIX B

Kenya Research License

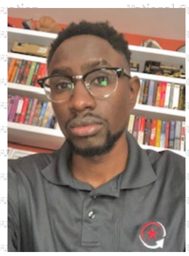
REPUBLIC OF KENYA

NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

Ref No: **239365**

Date of Issue: **05/June/2023**

RESEARCH LICENSE



This is to Certify that Mr.. Erick Kipkoech Kigen of Middle Tennessee State University, has been licensed to conduct research as per the provision of the Science, Technology and Innovation Act, 2013 (Rev.2014) in Baringo, Bomet, Elgeyo-Marakwet, Kericho, Nairobi, Nakuru, Nandi, Uasin-Gishu on the topic: Knowledge and Strategies of Heat Acclimation and Heat Acclimatization in Elite Runners for the period ending : 05/June/2024.

License No: **NACOSTI/P/23/26523**

239365

Applicant Identification Number

Director General
NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

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See overleaf for conditions

APPENDIX C

Survey Questions

Knowledge and Strategies of heat acclimatization used by elite middle- and long-distance runners

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Start of Block: Informed consent

Informed consent

Dear Participant,

You are being asked to participate in a research project conducted by Erick Kipkoech Kigen,Ph.D (Ab.D) the title of the project is Knowledge and Strategies of Heat Acclimation, Acclimatization in Elite Middle- And Long-Distance Runners. The primary investigator (PI) is a doctoral candidate at Middle Tennessee State University (MTSU) in the united States of America. The project has received IRB approval by MTSU and the PI has been granted research license to do research in Kenya by NACOSTI (Research review body in Kenya). The following information is provided to inform you about the research project and your participation in it.

1. Purpose of the study:

The overall purpose of this dissertation is to highlight the heat acclimation (HA) and heat acclimatization (HAz) knowledge, history of heat illness, and strategies used by elite middle-and long-distance runners in the United States and Kenya.

2. Description of procedures to be followed and approximate duration of the study:

As a participant: You will have a chance to read the entire informed consent to assist you in making a final decision on participation. After you read and understand the purpose of the study, you will be asked to complete the survey questions. The survey questions will include: demographics, knowledge and history of exertion heat illness, practices of heat acclimatization strategies, and the perception of the effectiveness of the heat acclimatization used in preparation for competition in hot and humid environment.

3. How long/time: You will be asked to fill out the survey questions once. The survey will not take you more than 10-15 minutes.

4. Compensation for participation: there is no compensation for participation.

5. Personal information: The data will be stored securely by the survey hosting site.

6. Withdrawing or refusing to participate: Completion of the survey is voluntary and optional. The participant is free to abstain from completing the survey and can opt out of the survey at any point prior to survey completion.

7. Here are your rights as a participant:

a) Your participation in this research is voluntary.
b) You may skip any item that you don't want to answer, and you may stop the research at any time. Note that if you leave an item blank, you will be warned that you missed one, just in case it was an accident. You can still click that you don't want to answer.
c) There are no risks associated with your participation besides possible discomfort with some of the questions.
d) There are no real benefits to you from participating besides the opportunity to reflect upon your training and readiness for competition in hot and humid conditions.
e) You will NOT be asked to provide any identifiable personal information.
f) All efforts, within reason, will be made to keep the personal information in your research record private, but total privacy cannot be promised. Your information may be shared with people at MTSU (such as the MTSU Institutional Review Board) or other agencies (such as the Federal Government Office for Human Research Protection) if you or someone else is in danger or if we are required to do so by law.

8. Contact Information: If you should have any questions about this research study please contact: Principal Investigator: Erick Kipkoech Kigen,Ph.D (Ab.D).
Contact Information: ek3i@mtmail.mtsu.edu or phone 5037036045.
Faculty Advisor: Dr. Jenn Caputo, Contact Information: jenn.caputo@mtsu.edu

For additional information about giving consent or your rights as a participant in this study, please contact the Middle Tennessee State University (MTSU) Office of Compliance at 615-494-8918 or via email at irb_information@mtsu.edu. (http://www.mtsu.edu/irb)

If you're ready to get started, please make your choice below before clicking the arrow button.
Thanks again for volunteering your time to this project!

Q1 I have read this informed consent document pertaining to the above identified research

◯ Yes

◯ No

Q2 The research procedures to be conducted are clear to me

◯ yes

◯ No

Q3 I confirm I am 18 years or older

◯ Yes

◯ No

Q4 I am aware of the potential risks and benefits of the study

◯ Yes

◯ No

Q5 By clicking below, I affirm that I freely and voluntary choose to participate in this study. I understand I can withdraw from this study at any time without facing any consequences.

◯ Yes

◯ No

End of Block: Informed consent

Start of Block: Demographics

Q1 What is your age?

____

Q2 Height

Inches	
Meters	

Q3 Body mass

Kilograms	
Pounds	

Q4 What is your sex?

- ○ Male
- ○ Female
- ○ Intersex
- ○ Prefer not to say

Q5 What is your race?

- ☐ White
- ☐ Black or African American
- ☐ American Indian or Alaska Native
- ☐ Asian
- ☐ Native Hawaiian or Pacific Islander
- ☐ Other ____

Page Break

Q6 What is your nationality?

- ◯ Kenyan (Enter the county you do most of your training in the text below)

  ____

- ◯ American (enter the state you do most of your training in the text below)

  ____

Q7 What is the highest level of school you have completed or the highest degree you have received?

- ◯ Less than high school degree
- ◯ High school graduate (high school diploma or equivalent including GED)
- ◯ Some college but no degree
- ◯ Associate degree in college (2-year)
- ◯ Bachelor's degree in college (4-year)
- ◯ Master's degree
- ◯ Doctoral degree
- ◯ Professional degree (JD, MD)

Q8 What is the total number of years you have been training and competing as professional runner?

- ◯ 0 to 9 years
- ◯ 10 to 15 years
- ◯ 16 to 20 years
- ◯ 21 to 30 years

Q9 What is your main running event?

- 800 m
- 1500 m
- 3000 m SC
- 5000 m
- 10000 m
- Half marathon
- Marathon

10 What is your best recorded time in your main running event? (For example; 800m time 1:44:50)

____

Page Break

Q11 Do you regularly train under the supervision of a coach, athletic trainer, strength and conditioning specialist, doctor, or any other healthcare professional? If choosing "other", list the specific professional in the text box below. Check all that apply.

- ☐ Coach
- ☐ Athletic trainer
- ☐ Strength and conditioning specialist
- ☐ Doctor
- ☐ None
- ☐ Any other health care specialist ____

Page Break

End of Block: Demographics

Start of Block: Knowledge of Heat Acclimatization

1 Have you ever received information regarding heat acclimation training protocols from any of the following sources? Select all that apply.

- ▢ Other elite runners
- ▢ Health professionals such as doctors, athletic trainers, etc.
- ▢ Current/former coaches, personal trainers, fitness instructors
- ▢ Magazines, books, television, YouTube, social media, online articles
- ▢ Peer reviewed research journals on training
- ▢ Other (please specify below)

____

- ▢ I don’t or have never received information regarding heat acclimation protocols

---

Q2 What is the daily duration of heat exposure needed when acclimating to the heat?

- ○ 30 minutes or less
- ○ 31-60 minutes
- ○ 61-90 minutes
- ○ More than 90 minutes

Q3 What time of the day would you consider most appropriate for heat acclimation/acclimatization?

- ☐ Before 8 am
- ☐ 8 am to 10 am
- ☐ 10 am to noon
- ☐ 3 pm to 6pm
- ☐ noon to 2 pm
- ☐ 2 pm - 4 pm
- ☐ 4 pm - 6 pm
- ☐ 6pm - 8 pm
- ☐ after 8 pm

Q4 How many days does it take to become fully heat acclimatized?

____

Q5 Should a runner maintain training intensity during a heat acclimatization period?

- ○ Yes
- ○ No

Q6 What are the benefits of a heat acclimation protocol? Select all that apply

- ☐ Gain advantage and improve running performance in hot and humid conditions.
- ☐ Decrease thermal comfort (feeling less hot running in hot and humid conditions)
- ☐ Reduce chances of heat illness during competition in hot and humid conditions
- ☐ Reduced perception of running effort in hot and humid conditions
- ☐ Increased heart rate while exercising
- ☐ Increased body temperature (core and skin) while exercising
- ☐ Increased sweat rate
- ☐ Improved cooling
- ☐ Decreased blood flow to working muscles
- ☐ Other ____

Q7 How many days without heat exposure will lead to decay of the benefits of heat acclimation?

____

Q8 Does heat acclimation improve endurance performance in hot and humid environments?

- ◯ Yes
- ◯ No

Q9 Does heat acclimation help decrease occurrence of exertional heat illness?

- ◯ Yes
- ◯ No

Q10 Which label best describes your social economic status?

- ◯ Low
- ◯ Middle
- ◯ High

Q11 My social economic status limits my heat acclimation resources:

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Scale	◯	◯	◯	◯	◯

Q12 My social economic status (SES) limits my knowledge of heat acclimatization (HAz) or heat acclimation (HA):

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Scale	○	○	○	○	○

End of Block: Knowledge of Heat Acclimatization

Start of Block: Experiences and History Exertion Heat Illness (EHI)

Q1 Have you ever been diagnosed with exertional heat illness from training or racing?

○ Yes

○ No

Display This Question:
If Q1 = Yes

Q2 If yes to 4 above, please specify the type of heat illness (Select all that apply)

▢ Dehydration

▢ Hyponatremia (low sodium)

▢ Heat exhaustion

▢ Heat stroke

▢ Other ____

Q3 Indicate the frequency you have experienced any of the following symptoms while running in hot and humid conditions in the past 12 months. (Select all that apply).

- ☐ Nausea
- ☐ Vomiting
- ☐ Muscle cramps
- ☐ Headaches
- ☐ Dizziness
- ☐ Fainting
- ☐ Lightheadedness
- ☐ Confusion
- ☐ I have not experience any of the above symptoms (Type on the text below any symptom you have experienced, if not listed above)

____

Q4 Have you ever had to end a training session or race due to symptoms of overheating?

- ○ Yes
- ○ No

Q5 Have you ever felt your performance suffered due to overheating during competition or training?

- ○ Yes
- ○ No

Q6 Do you consciously drink water or other beverages before training in hot and humid environments to ensure proper hydration?

- ☐ Water
- ☐ Sports beverage
- ☐ Other ____
- ☐ I do not drink water or any other kind of beverage before training

Q7 Do you consciously drink water or other beverages during training in hot/humid environments to ensure proper hydration?

- ☐ Water
- ☐ Sports beverage
- ☐ Other ____
- ☐ I do not drink water or any other kind of beverage before training

Q8 Do you weigh yourself before and after runs during the hotter months or while practicing HA to assess sweat losses?

- ○ Yes
- ○ No

Q9 Do you have any experience using heat training to improve endurance performance? (For example, sauna or hot water immersion post-exercise or training in a heat chamber)

○ Yes (If you select yes, type the mode you use for heat training.)
____

○ No

End of Block: Experiences and History Exertion Heat Illness (EHI)

Start of Block: Practices of Heat Acclimatization Strategies

Q1 How often do you practice heat acclimatization interventions before competing in hot and humid conditions? Percentage %: (0 Means Never to 100 meaning always)

	0 10 20 30 40 50 60 70 80 90 100
1	

2 What strategy(s) do you use to acclimate to high heat and humidity? Select all that apply.

▢ The natural environment

▢ A heat chamber

▢ Excess clothing

▢ Hot water immersion

▢ Sauna

▢ If preferred method is not listed above, please specify below
____

Q3 When practicing heat acclimation/acclimatization, do you decrease, increase, or maintain any of the following training variables? Click your responses below.

	Decrease	Maintain	Increase
Mileage	○	○	○
Intensity	○	○	○
Duration	○	○	○
Frequency	○	○	○

Q4 What type(s) of training do you do during your heat acclimation phase? Select all that apply

- ☐ Tempo run
- ☐ Intermittent tempo training
- ☐ Intervals/fartlek
- ☐ Low intensity long duration
- ☐ Moderate intensity long duration
- ☐ Hill work training
- ☐ Time trials
- ☐ Recovery/easy run
- ☐ Other ____

Q5 What exercise intensity/intensities do you use while undergoing heat exposures?

- ☐ Light intensity (90 -130 bpm) – 1
- ☐ Moderate intensity (130 – 160 bpm) – 2
- ☐ High intensity (Above 160 bpm) – 3
- ☐ Prefer passive heat exposure (e.g., hot tub or sauna)? 0 intensity

Q6 How many heat exposures do you perform in preparation for competition in a hot and humid environment?

____

Q7 How many days do you arrive to the competition venue prior to running in your event?

____

Q8 Do you use any other interventions or any modification protocols apart from heat acclimation to mitigate heat stress during competition in hot and humid conditions?

- ○ Yes (If you select yes, explain below)

____

- ○ No

Q9 On a scale of 0 (Not effectiveness) to 10 (max effectiveness), (5 is Not sure), what is your perception on the effectiveness of heat acclimation (HA) or Heat acclimatization (HAz) protocol you use to prepare for competition in hot and humid environment?

	0 1 2 3 4 5 6 7 8 9 10
1	

End of Block: Practices of Heat Acclimatization Strategies

APPENDIX D

Email Recruitment Letter for US Runners

Recruitment Email

Dear Elite Runner (or Coach),

My name is Erick Kigen. I am a doctoral student at Middle Tennessee State University. Kindly, I am contacting you to seek your participation in the study I am conducting for my dissertation. The survey will take approximately 10 -15 minutes to complete.

The purpose of this dissertation is to highlight the heat acclimation and heat acclimatization knowledge and strategies used by elite middle-and long-distance runners to prepare for competitions in a hot and humid environment. I am asking for your voluntary participation or that you forward this email to the runner(s) you coach.

This study will present no apparent risk to you and completion is optional and voluntary. You are free to abstain from participation in this survey and can opt out of the survey at any point prior to survey completion. The questions pose no psychological concerns. The questions pertain to subjective and objective information relative to heat acclimation and acclimatization knowledge, history of heat illness, and practices of heat acclimation strategies. You will not be providing personally identifying information in the survey.

All survey data collected will be stored securely through the online survey system. Your participation in this study will not have any direct benefit other than the opportunity to reflect on your training and readiness to compete in hot and humid conditions.

Yours Sincerely,

Erick Kigen

Qualtrics link for survey:

https://mtsu.ca1.qualtrics.com/jfe/form/SV_etlujbcsSwhpSHY

APPENDIX E

Email Recruitment Letter for Kenyan Runners

Recruitment Email

Dear Elite Runner (or Coach),

My name is Erick Kigen. I am a doctoral student at Middle Tennessee State University. Kindly, I am contacting you to seek your participation in the study I am conducting for my dissertation. The survey will take approximately 10 -15 minutes to complete.

The purpose of this dissertation is to highlight the heat acclimation and heat acclimatization knowledge and strategies used by elite middle-and long-distance runners to prepare for competitions in a hot and humid environment. I am asking for your voluntary participation or that you forward this email to the runner(s) you coach.

This study will present no apparent risk to you and completion is optional and voluntary. You are free to abstain from participation in this survey and can opt out of the survey at any point prior to survey completion. The questions pose no psychological concerns. The questions pertain to subjective and objective information relative to heat acclimation and acclimatization knowledge, history of heat illness, and practices of heat acclimation strategies. You will not be providing personally identifying information in the survey.

All survey data collected will be stored securely through the online survey system. Your participation in this study will not have any direct benefit other than the opportunity to reflect on your training and readiness to compete in hot and humid conditions.

Yours Sincerely,

Erick Kigen

Qualtrics link for survey:

https://mtsu.ca1.qualtrics.com/jfe/form/SV_6XSnhQtsi5wiRoi

CHAPTER IV

STRATEGIES OF HEAT ACCLIMATION AND ACCLIMATIZATION USED BY ELITE MIDDLE- AND LONG-DISTANCE RUNNERS IN KENYA AND THE UNITED STATES

Introduction

Extreme heat stress and humidity are major concerns for middle- and long-distance runners competing at the summer Olympics and world athletic championships where the weather is often hot and humid (35°C, 60% RH). The high-risk temperatures range is 23 to 28°C (73 - 82°F). Environmental heat stress and physical exercise synergistically interact to increase physiological strain and thermal discomfort in elite runners (Sawka et al., 2015) leading to negative consequences to endurance performance and health. Heat acclimation (HA, artificial exposures) and acclimatization (HAz, natural exposures) are the foremost strategies that confer physiological adjustments to reduce these negative effects on performance and the occurrence of exertional heat illness (EHI; Racinais et al., 2015).

While an athlete can become acclimatized naturally by training in hot environments, there are other alternative HA strategies that can be used by elite runners. Promising alternative HA strategies include passive methods such as postexercise hot water immersion (HWI) or sauna bathing (Scoon et al., 2007; Zurawlew et al., 2016). Alternative active HA methods include using a heat chamber and overdressing in temperate conditions. Overdressing may be the simplest, most cost-effective model while also being the least likely to disrupt a runner's training program. Considering elite runners come from different backgrounds in terms of geographical locations and have varying social economic status it is important to understand how different techniques are beneficial to different athletes.

Currently, there is a scarcity of studies comparing elite runners from different social economic backgrounds and physical locations. It is possible that athletes from less advantaged countries may use less expensive or modified modes of HAz than athletes from wealthier countries. Therefore, the purpose of this study was to investigate the HA and HAz strategies and their perceived effectiveness in elite middle- and long-distance runners in the United States and in Kenya. The specific research questions asked were:(a) Are there differences in heat acclimation strategies and training techniques (intensity, volume, duration, frequency, mode, and intensity modification) used by runners from Kenya and the United States? (b) Are there differences in preparation between Kenya and US elite runners when traveling to a hot and humid competition event? (c) how does perception of effectiveness of heat acclimation strategies vary between elite runners from Kenya and the United States?

Methods

Participants

The 30 participants were male (n = 27 and female (n =3) elite middle- and long-distance runners with an average age of 29.4 years (SD = 6.2 years) from Kenya (n = 19) and the United States (n = 11). The sample of elite runners included in the study specialized in running events between 800 meters and the marathon, the inclusion criteria required was a qualifying time for national or international level competitions, in their respective events. The study was approved by the university institutional review board (see Appendix A) and the National Commission for Science, Technology, and Innovation (NACOSTI) Kenyan research review board (see Appendix B) and all participants provided informed consent before beginning the online survey.

Survey

The survey questions (see Appendix C) were generated by the primary investigator and adapted from Gipson et al. (2019), Heatherly et al. (2023), Macon (2022), and Periad et al. (2017). The questionnaire had four sections: Demographics, knowledge of HA, history of EHI, and practices of HA strategies sections. The participants completed the demographics questions, and questions on their practices of heat acclimation strategies and their perception of the effectiveness of the HA protocols. The nine demographics questions included age and sex of the participants, height and body mass, education level, geographic location, years of training and racing history, and event of participation. The participants also completed eight questions on their practices of HA and HAz practices and strategies with one question of perception of effectiveness of HA protocol they used. Questions on the practice and use of HA strategies included: Modes of HA and HAz, method of heat exposure and transference, intensity and duration of heat exposure, and number of heat exposures prior to travel to competition in hot and humid competition venue. Prior to distribution, survey questions were reviewed for clarity by experts in elite running and consultants. The survey was administered using the Qualtrics online survey platform (Qualtrics XM, Provo, Utah, USA).

Procedures

The participants were recruited during summer 2023. A recruitment email (see Appendix D and E) was sent directly to the elite runners, through respective Kenyan and United States athlete representatives, word of mouth to the elite runners in the training camps, and through coaches of elite runners from different training camps. An email (see Appendixes D and E) containing a brief introductory message, informed consent, and a link to the survey was sent to the available email addresses of elite runners or to coaches and federation athlete's representatives. The participants were asked to complete the survey within a two-week period with a reminder email sent out after one week. The survey took approximately 10 -15 minutes to complete.

Statistical Analysis

Frequencies and percentages are reported for the categorical variables. Fisher's exact tests were used to compare Kenya and US elite runners for the categorical variables. Means (*M*) and standard deviations (*SD*) are reported for the quantitative variables. Welch confidence intervals were used to estimate differences in the quantitative variables for Kenya and US elite runners. An alpha of .05 was used for each test. All statistical procedures were completed using SAS Studio version 3.81 (SAS Institute Inc., Cary, NC).

Results

There were no significant differences between Kenya and US runners with respect to the strategies (natural environment, heat chamber, excess clothing, hot water immersion, sauna, or other strategies) used for heat acclimation. Kenya and US runners decreased, maintained, or increased volume, intensity, duration, and frequency at similar rates of training while undergoing heat acclimation (see Table 1). The Kenya and US elite runners had no significant differences in the type of training mode (tempo run, intervals, fartlek, slow or moderate run, time trials, or recovery run). However, a greater percentage of US runners (54.6%) trained on hills compared to Kenyan runners (15.8%). Intensity modification rates during heat exposure were similar for Kenya and US elite runners (see Table 2). The number of heat exposures performed in preparation for competition in a hot and humid environment were similar for Kenya (*M* = 10.7, *SD* = 11.8) and US (*M* = 5.8, *SD* = 2.1) elite runners (Mean Difference = 4.9, 95% CI [-3.65, 13.38]). Kenya (*M* = 3.2 days before, *SD* = 1.9) and US (*M* = 3.0 days before, *SD* = 0.9) elite runners had similar arrival dates to the competition venue prior to the race (Mean Difference = 0.21, 95% CI [-0.91, 1.32]). Perception of effectiveness of heat acclimation strategies were similar for Kenyan (*M = 6.7, SD = 1.9*, 95% CI = 5.8 – 7.7) and US (*M = 8.0, SD = 1.5,* 95% CI = 6.9 – 9.1) runners (Mean Difference = -1.26, 95% CI [-2.60, 0.08]). While the perceptions did not statistically differ by nationality, the confidence intervals indicate the techniques were perceived as effective because the confidence intervals for each group of runners are higher than 5 (the neutral rating).

Table 1

Percentages for HA Strategies and Changes in Training of Kenya and US Elite Runners

Variable	Kenya (n = 19)	US (n = 11)	Fisher's Exact p Value
Strategies of HA			
Natural environment	52.6%	72.7%	.44
Heat chamber	26.3%	9.1%	.37
Excess clothing	26.3%	9.1%	.37
Hot water immersion	31.6%	18.2%	.67
Sauna	31.6%	36.4%	1.00
Other strategies	5.6%	0.0%	1.00
Changes in training during HA			
Intensity			.35
Decrease	37.5%	45.5%	
Maintain	43.8%	54.5%	
Increase	18.7%	0.00%	
Volume (miles)			.25
Decrease	36.8%	9.1%	
Maintain	42.1%	72.7%	
Increase	20%	0.0%	
Duration			.18
Decrease	26.7%	9.1%	
Maintain	53.3%	90.9%	
Increase	20%	0.0%	
Frequency			.41
Decrease	14.3%	9.1%	
Maintain	64.3%	90.9%	
Increase	21.4%	0.0%	

Note. HA = Heat acclimation. US = United States.

Table 2

Percentages for Training Mode and Intensities of Kenya and US Elite Runners

Variable	Kenya (n = 19)	US (n =11)	Fisher's Exact p Value
Mode of training during HA phase			
Tempo run	57.9%	45.5%	.71
Intervals	89.5%	81.8%	.61
Fartlek	68.4%	45.5%	.27
Long slow intensity	52.6%	36.4%	.47
Long moderate intensity	68.4%	36.4%	.13
Trained on hills	15.8%	54.6%	.04*
Time trials	0.0%	9.1%	.37
Recovery	36.8%	54.6%	.45
Other mode of training	0.0%	0.0%	---
Intensity modification during heat exposure			
Light	31.6%	63.6%	.13
Moderate	63.2%	72.7%	.28
High	21.1%	18.2%	1.00
Passive	5.3%	0.0%	1.00

Note. * = $p < .05$. HA = Heat acclimation.

Discussion

Running events such as the Doha 2019 World Athletic Championships and the Tokyo 2020 Olympic Games took place in hot and humid environments. The heat stress from racing in these conditions can negatively impact endurance performance and can be detrimental to an athlete's health. Consensus recommendations for elite runners suggest practicing HA and HAz to reduce heat intolerance and physiological strain (Periad et al.,2015; Racinais et al., 2015). Reinforcing the practice of these recommendations, Galan-Lopez et al. (2022) found that elite runners who performed even a modest amount of HA and HAz, placed higher than those who did not, and were less likely to require medical attention. There are limited data on the common HA and HAz practices by East Africans who dominate in middle-and long-distance events in these championships. Therefore, the purpose of this study was to investigate and compare the HA and HAz strategies and their perceived effectiveness in elite runners from the US and from Kenya.

Elite runners from the US and Kenya reported similar HA and HAz strategies (all using sauna bathing, hot water immersion, natural environment, heat chamber, and excess clothing) and did not differ in their overall perception of the effectiveness of these strategies however both groups did perceive their training techniques as effective. Athletes from both countries (72.7% of US and 52.6% of Kenyan runners) reported using the natural environment as a HAz technique the most while training at a moderate intensity. This outcome supports literature on collegiate runners documenting the natural environment was also the preferred technique of surveyed coaches from competitive collegiate programs in the US. Macon (2020) reported 73.7% of coaches in the sample selected natural environment as the most common heat exposure technique. This active technique of HAz is suitable for most elite runners because it mimics the competition environment. The HAz that occurs by training in the natural environment is one of the foremost strategies that confers physiological adjustments to reduce the negative effects of heat stress on performance and the occurrence of EHI (Racinais et al., 2015). Runners exposed to heat stress in a natural environment can control the duration of exposure and train in conditions that will match those during competition. The only foreseen challenge with this strategy is the cost of travel and expenses of setting up a heat camp. For these reasons, a natural environment might not also be applicable or practical to runners residing in temperate or cold environments. Elite runners in temperate or colder environments can use other active HA and HAz strategies such as excess clothing or a heat chamber. They can also incorporate passive HA strategies such as HWI or sauna bathing in their training programs. In the current sample of runners, sauna bathing was the preferred passive HA strategy (36.4% of US and 31.6% of Kenyan runners).

In addition to the reported HA and HAz strategies, the intensity, duration, frequencies, volume, and mode of training during heat exposure period were also compared between the US runners and the Kenyan runners. There were no significant differences in the changes in training between the runners from the US and the runners from Kenya during their HA and HAz practices. Most runners from both countries maintained training intensity, volume, duration, and frequency while undergoing heat exposure. Specifically, the runners in the US sample were consistent in maintaining these training characteristics with the only variability showing up in some US athletes decreasing their training intensity during heat exposure periods. The sample of Kenyan runners showed greater variability, with a percentage of the athletes either decreasing, maintaining, or increasing each of the noted training characteristics during heat exposures (see Table 1). The number of heat exposures prior to competition in a hot and humid environment did not differ significantly between the groups of runners. The US elite runners reported an average of 10 heat exposures or 17 training days while the Kenyan elite runners reported 6 heat exposures or 9 training days. Both groups were within the number of days and heat exposures suggested for the benefits of HA and Haz (Periad et al., 2015; Sawka et al., 2011; Tyler et al., 2016).

The runners also reported the training modality they used while doing HA and HAz. Options included Fartlek, long slow run, long moderate intensity run, intervals, hill work, and recovery runs. The most common modality chosen was interval training (81.8% of US and 89.5% of Kenyan runners). One difference between the groups was only the runners from the US indicated the use of hill work. This difference could be due to the geographic availability or lack thereof of hills at location the elite runners are doing most of their training.

In conclusion, HA and HAz methods are an important and consistent component of preparation leading up to competitions in hot and humid environments for elite runners from the US and from Kenya. The consistency of practices across countries illustrates runners are receiving similar information relative to effective practices. Overall, the results from this study showed elite middle- and long-distance runners from the US and from Kenya approached the process of HA and Haz in similar fashions prior to competitions in hot and humid environments. There were no significant differences with respect to the active and passive strategies used, changes in training characteristics, or the number of days and amount of heat exposure before travel. The modality chosen by most runners while practicing HA and HAz was interval training with hill training being the only different practice by the US runners. Overall, current data indicate that elite runners from countries with varying locations and climates participate in similar HA and HAz practices to improve endurance performance and mitigate detrimental effects of heat stress while competing in hot and humid environments.

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APPENDIXES FOR STUDY II

APPENDIX A

IRB Approval Letter

Office of Research Compliance
2269 Middle Tennessee Blvd.
Sam H. Ingram Bldg (ING) Room 010A
Box 124
Murfreesboro, TN 37132
www.mtsu.edu/irb

Date: June 8, 2023
PI: Erick Kigen
Department: Middle Tennessee State University, Psychology, Health and Human Performance
Re: Initial - IRB-FY2023-189
Knowledge and Strategies of Heat Acclimation and Heat Acclimatization in Elite Runners

The Middle Tennessee State University Institutional Review Board has reviewed and approved by Expedited Review the above referenced research study. The approval is effective starting June 8, 2023.

Decision: Approved
Category: 7. Research on individual or group characteristics or behavior (including, but not limited to, research on perception, cognition, motivation, identity, language, communication, cultural beliefs or practices, and social behavior) or research employing survey, interview, oral history, focus group, program evaluation, human factors evaluation, or quality assurance methodologies. (NOTE: Some research in this category may be exempt from the HHS regulations for the protection of human subjects. 45 CFR 46.101(b)(2) and (b)(3). This listing refers only to research that is not exempt.)

APPENDIX B

Kenya Research License

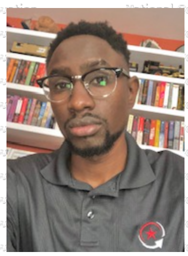
REPUBLIC OF KENYA

NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

Ref No: **239365**

Date of Issue: **05/June/2023**

RESEARCH LICENSE



This is to Certify that Mr.. Erick Kipkoech Kigen of Middle Tennessee State University, has been licensed to conduct research as per the provision of the Science, Technology and Innovation Act, 2013 (Rev.2014) in Baringo, Bomet, Elgeyo-Marakwet, Kericho, Nairobi, Nakuru, Nandi, Uasin-Gishu on the topic: Knowledge and Strategies of Heat Acclimation and Heat Acclimatization in Elite Runners for the period ending : 05/June/2024.

License No: **NACOSTI/P/23/26523**

239365

Applicant Identification Number

Director General
NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

Verification QR Code

NOTE: This is a computer generated License. To verify the authenticity of this document, Scan the QR Code using QR scanner application.

See overleaf for conditions

APPENDIX C

Survey Questions

Knowledge and Strategies of heat acclimatization used by elite middle- and long-distance runners

---

Start of Block: Informed consent

Informed consent

Dear Participant,

You are being asked to participate in a research project conducted by Erick Kipkoech Kigen,Ph.D (Ab.D) the title of the project is Knowledge and Strategies of Heat Acclimation, Acclimatization in Elite Middle- And Long-Distance Runners. The primary investigator (PI) is a doctoral candidate at Middle Tennessee State University (MTSU) in the united States of America. The project has received IRB approval by MTSU and the PI has been granted research license to do research in Kenya by NACOSTI (Research review body in Kenya). The following information is provided to inform you about the research project and your participation in it.

1. Purpose of the study:

The overall purpose of this dissertation is to highlight the heat acclimation (HA) and heat acclimatization (HAz) knowledge, history of heat illness, and strategies used by elite middle-and long-distance runners in the United States and Kenya.

2. Description of procedures to be followed and approximate duration of the study:

As a participant: You will have a chance to read the entire informed consent to assist you in making a final decision on participation. After you read and understand the purpose of the study, you will be asked to complete the survey questions. The survey questions will include: demographics, knowledge and history of exertion heat illness, practices of heat acclimatization strategies, and the perception of the effectiveness of the heat acclimatization used in preparation for competition in hot and humid environment.

3. How long/time: You will be asked to fill out the survey questions once. The survey will not take you more than 10-15 minutes.

4. Compensation for participation: there is no compensation for participation.

5. Personal information: The data will be stored securely by the survey hosting site.

6. Withdrawing or refusing to participate: Completion of the survey is voluntary and optional. The participant is free to abstain from completing the survey and can opt out of the survey at any point prior to survey completion.

7. Here are your rights as a participant:

a) Your participation in this research is voluntary.
b) You may skip any item that you don't want to answer, and you may stop the research at any time. Note that if you leave an item blank, you will be warned that you missed one, just in case it was an accident. You can still click that you don't want to answer.
c) There are no risks associated with your participation besides possible discomfort with some of the questions.
d) There are no real benefits to you from participating besides the opportunity to reflect upon your training and readiness for competition in hot and humid conditions.
e) You will NOT be asked to provide any identifiable personal information.
f) All efforts, within reason, will be made to keep the personal information in your research record private, but total privacy cannot be promised. Your information may be shared with people at MTSU (such as the MTSU Institutional Review Board) or other agencies (such as the Federal Government Office for Human Research Protection) if you or someone else is in danger or if we are required to do so by law.

8. Contact Information: If you should have any questions about this research study please contact: Principal Investigator: Erick Kipkoech Kigen,Ph.D (Ab.D).
Contact Information: ek3i@mtmail.mtsu.edu or phone 5037036045.
Faculty Advisor: Dr. Jenn Caputo, Contact Information: jenn.caputo@mtsu.edu

For additional information about giving consent or your rights as a participant in this study, please contact the Middle Tennessee State University (MTSU) Office of Compliance at 615-494-8918 or via email at irb_information@mtsu.edu. (http://www.mtsu.edu/irb)

If you're ready to get started, please make your choice below before clicking the arrow button.
Thanks again for volunteering your time to this project!

Q1 I have read this informed consent document pertaining to the above identified research

- ○ Yes
- ○ No

Q2 The research procedures to be conducted are clear to me

- ○ yes
- ○ No

Q3 I confirm I am 18 years or older

- ○ Yes
- ○ No

Q4 I am aware of the potential risks and benefits of the study

- ○ Yes
- ○ No

Q5 By clicking below, I affirm that I freely and voluntary choose to participate in this study. I understand I can withdraw from this study at any time without facing any consequences.

- ○ Yes
- ○ No

End of Block: Informed consent

Start of Block: Demographics

Q1 What is your age?

____

Q2 Height

Inches	
Meters	

Q3 Body mass

Kilograms	
Pounds	

Q4 What is your sex?

- ○ Male
- ○ Female
- ○ Intersex
- ○ Prefer not to say

Q5 What is your race?

- ☐ White
- ☐ Black or African American
- ☐ American Indian or Alaska Native
- ☐ Asian
- ☐ Native Hawaiian or Pacific Islander
- ☐ Other ____

Page Break

Q6 What is your nationality?

◯ Kenyan (Enter the county you do most of your training in the text below)

____

◯ American (enter the state you do most of your training in the text below)

____

Q7 What is the highest level of school you have completed or the highest degree you have received?

◯ Less than high school degree

◯ High school graduate (high school diploma or equivalent including GED)

◯ Some college but no degree

◯ Associate degree in college (2-year)

◯ Bachelor's degree in college (4-year)

◯ Master's degree

◯ Doctoral degree

◯ Professional degree (JD, MD)

Q8 What is the total number of years you have been training and competing as professional runner?

◯ 0 to 9 years

◯ 10 to 15 years

◯ 16 to 20 years

◯ 21 to 30 years

Q9 What is your main running event?

- ◯ 800 m
- ◯ 1500 m
- ◯ 3000 m SC
- ◯ 5000 m
- ◯ 10000 m
- ◯ Half marathon
- ◯ Marathon

10 What is your best recorded time in your main running event? (For example; 800m time 1:44:50)

____

Page Break

Q11 Do you regularly train under the supervision of a coach, athletic trainer, strength and conditioning specialist, doctor, or any other healthcare professional? If choosing "other", list the specific professional in the text box below. Check all that apply.

▢ Coach

▢ Athletic trainer

▢ Strength and conditioning specialist

▢ Doctor

▢ None

▢ Any other health care specialist ____

Page Break

End of Block: Demographics

Start of Block: Knowledge of Heat Acclimatization

1 Have you ever received information regarding heat acclimation training protocols from any of the following sources? Select all that apply.

- ☐ Other elite runners
- ☐ Health professionals such as doctors, athletic trainers, etc.
- ☐ Current/former coaches, personal trainers, fitness instructors
- ☐ Magazines, books, television, YouTube, social media, online articles
- ☐ Peer reviewed research journals on training
- ☐ Other (please specify below)

____

- ☐ I don’t or have never received information regarding heat acclimation protocols

---

Q2 What is the daily duration of heat exposure needed when acclimating to the heat?

- ○ 30 minutes or less
- ○ 31-60 minutes
- ○ 61-90 minutes
- ○ More than 90 minutes

Q3 What time of the day would you consider most appropriate for heat acclimation/acclimatization?

- ☐ Before 8 am
- ☐ 8 am to 10 am
- ☐ 10 am to noon
- ☐ 3 pm to 6pm
- ☐ noon to 2 pm
- ☐ 2 pm - 4 pm
- ☐ 4 pm - 6 pm
- ☐ 6pm - 8 pm
- ☐ after 8 pm

Q4 How many days does it take to become fully heat acclimatized?

____

Q5 Should a runner maintain training intensity during a heat acclimatization period?

- ○ Yes
- ○ No

Q6 What are the benefits of a heat acclimation protocol? Select all that apply

- ☐ Gain advantage and improve running performance in hot and humid conditions.
- ☐ Decrease thermal comfort (feeling less hot running in hot and humid conditions)
- ☐ Reduce chances of heat illness during competition in hot and humid conditions
- ☐ Reduced perception of running effort in hot and humid conditions
- ☐ Increased heart rate while exercising
- ☐ Increased body temperature (core and skin) while exercising
- ☐ Increased sweat rate
- ☐ Improved cooling
- ☐ Decreased blood flow to working muscles
- ☐ Other ____

Q7 How many days without heat exposure will lead to decay of the benefits of heat acclimation?

____

Q8 Does heat acclimation improve endurance performance in hot and humid environments?

- Yes
- No

Q9 Does heat acclimation help decrease occurrence of exertional heat illness?

- Yes
- No

Q10 Which label best describes your social economic status?

- Low
- Middle
- High

Q11 My social economic status limits my heat acclimation resources:

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Scale	○	○	○	○	○

Q12 My social economic status (SES) limits my knowledge of heat acclimatization (HAz) or heat acclimation (HA):

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Scale	○	○	○	○	○

End of Block: Knowledge of Heat Acclimatization

Start of Block: Experiences and History Exertion Heat Illness (EHI)

Q1 Have you ever been diagnosed with exertional heat illness from training or racing?

○ Yes

○ No

Display This Question:
If Q1 = Yes

Q2 If yes to 4 above, please specify the type of heat illness (Select all that apply)

▢ Dehydration

▢ Hyponatremia (low sodium)

▢ Heat exhaustion

▢ Heat stroke

▢ Other ____

Q3 Indicate the frequency you have experienced any of the following symptoms while running in hot and humid conditions in the past 12 months. (Select all that apply).

- ☐ Nausea
- ☐ Vomiting
- ☐ Muscle cramps
- ☐ Headaches
- ☐ Dizziness
- ☐ Fainting
- ☐ Lightheadedness
- ☐ Confusion
- ☐ I have not experience any of the above symptoms (Type on the text below any symptom you have experienced, if not listed above) ________________________________

Q4 Have you ever had to end a training session or race due to symptoms of overheating?

- ○ Yes
- ○ No

Q5 Have you ever felt your performance suffered due to overheating during competition or training?

- ○ Yes
- ○ No

Q6 Do you consciously drink water or other beverages before training in hot and humid environments to ensure proper hydration?

- ☐ Water
- ☐ Sports beverage
- ☐ Other ____
- ☐ I do not drink water or any other kind of beverage before training

Q7 Do you consciously drink water or other beverages during training in hot/humid environments to ensure proper hydration?

- ☐ Water
- ☐ Sports beverage
- ☐ Other ____
- ☐ I do not drink water or any other kind of beverage before training

Q8 Do you weigh yourself before and after runs during the hotter months or while practicing HA to assess sweat losses?

- ○ Yes
- ○ No

Q9 Do you have any experience using heat training to improve endurance performance? (For example, sauna or hot water immersion post-exercise or training in a heat chamber)

○ Yes (If you select yes, type the mode you use for heat training.)
____

○ No

End of Block: Experiences and History Exertion Heat Illness (EHI)

Start of Block: Practices of Heat Acclimatization Strategies

Q1 How often do you practice heat acclimatization interventions before competing in hot and humid conditions? Percentage %: (0 Means Never to 100 meaning always)

	0 10 20 30 40 50 60 70 80 90 100
1	

2 What strategy(s) do you use to acclimate to high heat and humidity? Select all that apply.

▢ The natural environment

▢ A heat chamber

▢ Excess clothing

▢ Hot water immersion

▢ Sauna

▢ If preferred method is not listed above, please specify below
____

Q3 When practicing heat acclimation/acclimatization, do you decrease, increase, or maintain any of the following training variables? Click your responses below.

	Decrease	Maintain	Increase
Mileage	○	○	○
Intensity	○	○	○
Duration	○	○	○
Frequency	○	○	○

Q4 What type(s) of training do you do during your heat acclimation phase? Select all that apply

- ☐ Tempo run
- ☐ Intermittent tempo training
- ☐ Intervals/fartlek
- ☐ Low intensity long duration
- ☐ Moderate intensity long duration
- ☐ Hill work training
- ☐ Time trials
- ☐ Recovery/easy run
- ☐ Other ________________________________

Q5 What exercise intensity/intensities do you use while undergoing heat exposures?

- ☐ Light intensity (90 -130 bpm) – 1
- ☐ Moderate intensity (130 – 160 bpm) – 2
- ☐ High intensity (Above 160 bpm) – 3
- ☐ Prefer passive heat exposure (e.g., hot tub or sauna)? 0 intensity

Q6 How many heat exposures do you perform in preparation for competition in a hot and humid environment?

____

Q7 How many days do you arrive to the competition venue prior to running in your event?

____

Q8 Do you use any other interventions or any modification protocols apart from heat acclimation to mitigate heat stress during competition in hot and humid conditions?

- ○ Yes (If you select yes, explain below)

____

- ○ No

Q9 On a scale of 0 (Not effectiveness) to 10 (max effectiveness), (5 is Not sure), what is your perception on the effectiveness of heat acclimation (HA) or Heat acclimatization (HAz) protocol you use to prepare for competition in hot and humid environment?

	0 1 2 3 4 5 6 7 8 9 10
1	

End of Block: Practices of Heat Acclimatization Strategies

APPENDIX D

Email Recruitment Letter for US runners

Recruitment Email

Dear Elite Runner (or Coach),

My name is Erick Kigen. I am a doctoral student at Middle Tennessee State University. Kindly, I am contacting you to seek your participation in the study I am conducting for my dissertation. The survey will take approximately 10 -15 minutes to complete.

The purpose of this dissertation is to highlight the heat acclimation and heat acclimatization knowledge and strategies used by elite middle-and long-distance runners to prepare for competitions in a hot and humid environment. I am asking for your voluntary participation or that you forward this email to the runner(s) you coach.

This study will present no apparent risk to you and completion is optional and voluntary. You are free to abstain from participation in this survey and can opt out of the survey at any point prior to survey completion. The questions pose no psychological concerns. The questions pertain to subjective and objective information relative to heat acclimation and acclimatization knowledge, history of heat illness, and practices of heat acclimation strategies. You will not be providing personally identifying information in the survey.

All survey data collected will be stored securely through the online survey system. Your participation in this study will not have any direct benefit other than the opportunity to reflect on your training and readiness to compete in hot and humid conditions.

Yours Sincerely,

Erick Kigen

Qualtrics link for survey:

https://mtsu.ca1.qualtrics.com/jfe/form/SV_etlujbcsSwhpSHY

APPENDIX E

Email Recruitment Letter for Kenyan runners

Recruitment Email

Dear Elite Runner (or Coach),

My name is Erick Kigen. I am a doctoral student at Middle Tennessee State University. Kindly, I am contacting you to seek your participation in the study I am conducting for my dissertation. The survey will take approximately 10 -15 minutes to complete.

The purpose of this dissertation is to highlight the heat acclimation and heat acclimatization knowledge and strategies used by elite middle-and long-distance runners to prepare for competitions in a hot and humid environment. I am asking for your voluntary participation or that you forward this email to the runner(s) you coach.

This study will present no apparent risk to you and completion is optional and voluntary. You are free to abstain from participation in this survey and can opt out of the survey at any point prior to survey completion. The questions pose no psychological concerns. The questions pertain to subjective and objective information relative to heat acclimation and acclimatization knowledge, history of heat illness, and practices of heat acclimation strategies. You will not be providing personally identifying information in the survey.

All survey data collected will be stored securely through the online survey system. Your participation in this study will not have any direct benefit other than the opportunity to reflect on your training and readiness to compete in hot and humid conditions.

Yours Sincerely,

Erick Kigen

Qualtrics link for survey:

https://mtsu.ca1.qualtrics.com/jfe/form/SV_6XSnhQtsi5wiRoi

CHAPTER V

OVERALL CONCLUSIONS

The overall purpose of this dissertation was to explore HA and HAz knowledge, history and symptoms of EHI, and strategies of HA and HAz of Kenya and US elite runners. The dissertation included a 41-question survey, completed online, by the runners. Participants read and signed an informed consent before completing the survey. The study was approved by the Middle Tennessee State University Institutional Review Board and a research license was awarded by the Kenya review board through the National Commission for Science, Technology & Innovation (NACOSTI). Participants had world class middle- and/or long-distance times that qualified for national and international competitions, such as the World Athletic Championships or Olympic Games.

In the first study, the differences in heat HA and HAz knowledge and the runners' experiences and symptoms of EHI were investigated. Demographics on age, height, weight, sex, race, nationality, level of education, years of training, running event and best time in the event participated were collected. The HA and HAz knowledge questions included: source of HA information, duration, intensity, preferable time of the day for heat exposure, and knowledge on benefits HA and HAz, In addition to the question on knowledge, we also inquired about the diagnosis of EHI in the past year of the elite runners completing the survey. This was to determine if the runners from Kenya and the United States experienced dehydration, hyponatremia, heat exhaustion, or heat stroke. The runners were asked to recall symptoms of overheating such as nausea, vomiting, muscle cramps, headaches, lightheadedness, dizziness, confusion, and syncope.

In the first study, there were no significant differences in knowledge or experiences with history and symptoms of EHI between the US and Kenyan elite runners. The level of knowledge of the elite runners in the current sample did not preclude the occurrence of these negative consequences. Therefore, education of both athletes and coaching staff on the best practices of HA and HAz is critical. It is important that athletes have access to evidence-based guidelines on preventing EHI and preserving endurance performance. It is also vital that researchers continue to understand conditions under which competitions are best delayed or moved based on environmental conditions.

In the second study we investigated the differences in HA and HAz strategies practiced by elite runners from Kenya and the US and how effective they perceived these practices to be. In addition to the different strategies (passive: hot water immersion and sauna bathing; active: natural environment, heat chamber, and excess clothing) used by Kenyan and elite runners, survey questions also inquired on heat exposure frequency, duration, volume (miles per week), mode (easy run, tempo, intervals, hill work, long run), and intensity modification. The runners were also asked about the duration of HA and HAz prior to travel and day of competition in hot and humid environment. Elite runners from the US and Kenya indicated that they practice HA and HAz prior to competition in hot and humid environments.

The practices of the runners from both countries leading up to competition in a hot and humid environment were consistent. The natural environment and sauna bathing were the most used active and passive strategies, respectively. The runners also were consistent in their perceived effectiveness of these strategies. The geographical terrain of the location of the runners may have contributed to the only difference in training modality, the use of hill work for US runners.

Overall Conclusions

Results from this dissertation document that elite runners from the US and from Kenya are consistent in their knowledge of and practices of HA and HAz. The geographic location where elite runners do most of their training did not affect choice of HA and HAz practices. However, the runners also showed consistency in their experiences of physiological symptoms of heat stress and EHI. These findings support the need for further research on HA and HAz training for elite runners to maximize endurance performance and reduce detrimental effects of heat stress. There is a need for greater evidence-based practice guidelines for coaches, runners, and the federations in charge of the athletes on techniques to mitigate the negative consequences of heat on performance and health.

Research needs to also extend to the environmental conditions that warrant the delay and/or movement of scheduled competitions due to extreme heat and/or humidity. Evidence-based information is necessary for universal precaution guidelines for race organizers on safety measures during competitions in hot and humid conditions. The small sample size of the current studies also calls for future research to investigate more practical, cost-effective methods such as excess clothing or modified HA and HAz techniques that do not disrupt training programs of elite runners. Future studies can also compare social economic status since we had a challenge in the current study due to majority of runners being in the same economic class. Finally, elite runners are encouraged to increase their own knowledge on HA and take responsibility in understanding individual physiological responses due to heat stress and how to push their bodies to tolerate extreme thermal discomfort. In the end, elite athletes are in search of any change that can provide a competitive edge and HA and HAz practices may aide in improving race outcome and maintaining health during competitions in hot and humid conditions.

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