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REVIEW ARTICLE

Impact of Heat Acclimatisation in Sports: A Narrative Review

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ABSTRACT

Background. The summer is a time for various sporting events, many of which take place in hot and humid environments. Heat exposure can have a significant impact on athletic performance and can even be fatal. Heat acclimatization (HA) is the process of gradually exposing the body to hot environments to improve its ability to regulate temperature and function in the heat. **Objectives.** This paper reviews the physiological changes associated with heat exposure and the effects of HA on athletic performance. It also provides recommendations for minimizing heat-related illness and death in sports. **Methods.** A literature search was conducted to identify relevant studies on HA and heat-related illness in sports. The search terms used included "heat acclimatization," "heat stress," "sport," and "performance". **Results.** Heat acclimatization induces a series of beneficial physiological adaptations that contribute to enhanced athletic performance in hot conditions. These changes include increased sweating, heart rate, and blood flow to the skin. Enhances thermoregulatory mechanisms, allowing the body to better cope with heat stress and improving sweat rate and electrolyte balance, aiding in more efficient cooling. Acclimatization results in increased plasma volume, reducing the risk of dehydration. Additionally, it promotes cardiovascular adaptations, enhancing overall heat tolerance. HA can lead to improved exercise performance in hot conditions, making it a valuable strategy for athletes and workers in warm environments. Therefore, proper HA can reduce the risk of heat exhaustion, and heatstroke. **Conclusion.** HA is an important tool for athletes who train and compete in hot environments. It can improve performance, reduce the risk of heat-related illness, and even save lives. Sports federations and coaches should encourage athletes to participate in HA programs. HA programs should include gradual exposure to hot environments, both with and without exercise.

KEYWORDS: ***Heat Acclimatization, Heat Adaptation, Sports Activities.***

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INTRODUCTION

During the summer months, many major sporting events take place, frequently at high environmental temperatures. Owing to physical preparation in unfavorable environmental conditions, most elite athletes partially acclimatized to the heat by changing their status adaptation to the changing needs (1). These adaptations might be insufficient from those completed with exposure to natural heat and do not substitute for acclimatization per se (2). As a result, getting attuned to the training condition under high heat has severe adverse effects such as rapid and easy fatigue, in addition, lactic acidosis build-up is more easily accumulated compared to either passive heat exposure or neutral-condition preparation (3). The exact or ideal HA techniques to give an absolute positive result, are not well-known to most elite athletes. It has recently emphasized the significance of HA for the players before the commencement of the competition as well as more calls into the research on the specific techniques to achieve these desires; HA by the players (4). HA can be defined as a biological adaptation that minimizes physiological stress (e.g., heart rate and body temperatures), which makes athletes feel more relaxed, enhances training ability, and decreases the risk of extreme heat illness through heat stress exposure.

Heat illnesses occur in virtually every aspect of world events that involve physical exercise or activities (e.g., cycling, running races, American football, soccer) and heat exhaustion. It occurs most commonly in hot-humid environments but can also happen during extreme or prolonged exercise in cold conditions (5-13). Heat cramps are painful muscle contractions that occur in workers or athletes as a result of the fluid replacement of profuse sweat with water, which causes hyponatremia (14). Moreover, heat cramps are caused by the loss of salt and water as a result of profuse sweating (15). They are characterized by cramps in the voluntary muscles, which occur often during exercise.

According to the epidemiological statistics from the United States, an average of 5946 persons are medicated per year. Each year, around 2.0 emergency department visits per 100,000 people are treated in hospitals due to heat sickness acquired while engaging in a sport or leisure activity (16). However, the incidence rates were significantly higher among men (72.5%) and those aged 15-19 years (35.6%), and 7.1% of patients were admitted. Another study using a survey of American football injury showed that there were between 1930 and 2009 cases, and about 13 deaths from exertional heat stroke that have been recorded by a study carried out by Rae et al., (2008) (17). Although the fatality rate is low, the heat illness demand for emergency care is high. During the 2002 Argus Cycle Tour in South Africa, five people died from exertional heatstroke while cycling (17).

Therefore, some individual sports such as those with physical contact and prolonged competition periods or games may have a serious condition of exercise/heat-related sickness and muscle injury if the players are not well acclimatized to the condition. Despite that, most participants in many sports are young talented individuals from college or recreational athletes but still present with heat when exposed to a such high-heat training session. Moreover, there is only minimal evidence recorded to date, suggesting a prevalent high risk of heat exertion among athletes throughout the companions (18). However, this does not indicate a lack of risk or alleviate the requirement to address heat-exertion-related issues by comprehensively outlining specific guidelines to reduce the possible dangers of exertional heat disease, especially among elite international athletes (19). Certain sports governing bodies such as the International Athletes Federation suggested some recommendations for avoiding match scheduling during the hottest times of the day to reduce the risk of exertional heat illness for participants. Some sports organizing committee employs systemic control of environmental conditions as an important preventive step. There are techniques and ideas that trainers, coaches, and athletes may follow in sports like the marathon (long-distance running) to optimally induce heat acclimation before a sports competition to enhance athletes' safety and welfare. Hence, this paper reviews physiological changes, acclimatization, and recommendations to minimize heat-related illness and death in sports to improve participant’s performance at all levels.

THE IMPORTANCE OF 14 DAYS OF ACCLIMATISATION

The adverse effects of heat illness can be seen in the record of the Tel Aviv race events from 2007 to 2013 which recorded the loss of two athletes for a sport-related fatality rate of approximately 1 in 69,000 (95 percent confidence interval: 0.4 to 5.3 in 100,000), and both deaths had been caused by heatstroke (20). This unfortunate news led to the creation of some guidelines aimed at minimizing heat-related morbidity and death exertional diseases in sports to improve participants' performance at all levels. The response to maximum HA takes up to 14 days, and the individual body system responds differently to this heat exposure impact (Figure 1) (21-26):

1. The HA cycle days 1 through 5 consists of the first 5 days of the regular practice. Athletes should not be allowed to engage in more than one practice a day during the acclimatization period.
2. If the practice is disrupted by harsh weather or heat constraints, the practice should not resume until the conditions are considered safe, and total practice time in any one day should not exceed 3 hours.
3. A 1-hour maximum walk-through time from day 1 to day 5 of the HA is permitted, but a 3-hour rest time between practice and walk-through (or vice versa) should be ensued.
4. In sports that require specific protective gear such as helmets or shoulder pads, a helmet should be the only protective equipment allowed (goalies, as in the case of contact sports) Only helmet and shoulder pads should be worn on day 3 to day 5, all the protective equipment may be worn starting on day 6, and full contact may commence. For only football: On day 3 to day 5, touch can be initiated with blocking sleds and tackling dummies, while for full-contact sports: Live contact drills of 100% should commence no earlier than day 6.
5. Beginning no earlier than day 6 and continuing until day 14, double-practice days must be followed by a single practice day. On a single-practice day, one walk-through is allowed, separated from the practice by at least 3 hours of continuous rest. If a double day of training is followed by a rest day, a further double day of training after the rest day is allowed.
6. Body stretching, warm-up conditioning, walk-throughs, and weight room exercises should be included as part of the exercise period. In a cool climate, the two activities should be separated by a minimum of 3 continuous hours. None of the sessions should reach 3 hours in duration on a day of double practice, and student-athletes should not participate in more than 5 hours of total practice.
7. Since there is a high risk of exertional HA during the pre-season period, we strongly suggest that an athletic trainer is on-site before, during, and after all workouts.

Due to the high risk of lethal hyperthermia, regulating body temperature in the heat during exercise becomes critical. Thermoregulatory adaptations (i.e., increased sweat rate: an earlier start of sweat production) coupled with cardiovascular changes lead to lower central body temperature.

After 5 to 8 days of the HA, this response would be maximized. HA performed in a hot-dry condition would stimulate a greater sweat rate than HA in a hot-humid environment.

PHYSIOLOGICAL RESPONSES TO HEAT ACCLIMATISATION

Responses to HA have been studied extensively in several works and research, military, and laboratory environments to boost knowledge among professional athletes and teams in their natural training environment (4). Physiological responses to HA are produced by repetitive exposure to hot climates in which the capacity to withstand heat stress is enhanced. Heat exposure exercise results in progressive changes in thermoregulation which involve sweating, and circulation of the skin, following which thermo-regulatory counter-response begins via cardiovascular changes and endocrine cleansing. These physiological adjustments help to minimize the disruption in the body's homeostasis due to heat stress. It has been reported that there is high individual variability in the physiological response to heat disease among players. However, many of the athletes are trained to utilize the condition to achieve high-performance benefits (27). Racinais et al., (2012) indicated that, after the HA period, players try to build excellent heat adaptation responses to be able to maintain their physical demand level when the sport is conducted in the heat. Similarly, players that have lower adaptation responses will produce decreased performance (27).

HA practice has a lot of benefits that have been shown to enhance physical performance in temperate environmental conditions; however, the relationship between the performance changes in warm and temperate environments and the underlying mechanisms is not well established (28, 29). Bergeron et al., (2012) (4) reported that significant inter-individual differences in the ergogenic impact of a high-level soccer player acclimatization camp indicate that players who did not wholly acclimatize had decreased running performance and endurance in a hot environment. On the other hand, those with the best acclimatization responses were able to sustain their running action when playing in the heat for the length of the exercise period.

There are many physiological reasons for the improvements in the performance observed in the athletes following HA. Previous studies showed the presence of near-normal heart rate, body core temperature, and less fatigue during standardized training drills at the end of the player's acclimatization process (Figure 2). One possible explanation or theory associated with the improvement in the performance in the running after HA in hot ambient conditions was the increase in the Yo-Yo intermittent recovery test level 2 (YoYoIR2) output. YoYoIR2 was developed to test an athlete's ability to perform high-intensity intermittent aerobic exercise with a significant anaerobic component. This version of the Yo-Yo test is widely used to assess elite and professional adult athletes' aerobic capacity (30). The adaptations to HA can reduce relative exercise intensity, enhance myocardial efficiency and, in turn, improve maximal cardiac output (28). After the HA camp, it was observed that athletes have an increased quantity of YoYoIR2 when analyzed (31). Buchheit et al., (2011) (28) demonstrated that after an outdoor HA camp, soccer players increased their output during the YoYoIR1 test by showing a decrease in the sub-maximum heart rate response, lower core skin temperature, and fatigue. The increase in plasma volume and extracellular fluid volume induced by HA helps to improve the maximum cardiac output (11), and this may account for the improvement in the efficiency of the athletes during an incremental temperature test (11, 32, 33). Hue et al., (2007) (34) reported that swimmers who perform swimming in a tropical climate had greater progress in performance, and displayed increased work output after returning to the temperate environment than swimmers who kept exercising in the non-temperate environment.

HA improves thermoregulation by increasing whole-body sweat loss, and reducing heart rate and core temperature during rest and exercise in the heat (35, 36). Sweating is a key mode of heat loss, and HA causes a number of sudomotor adaptations, including a lower core temperature at the beginning of sweating and increased sweating sensitivity, as evidenced by a higher sweat production for a given core temperature (36). Lorenzo et al., (2010) (29) indicated that laboratory acclimatization in temperate environments would increase physical fitness and sports performance.

Acclimatization to the hot environment leads to different physiological adaptations which could explain the changes in the improvement of physical performance. Also, systemic metabolism can be adversely affected by poor HA such as reduced oxygen uptake during submaximal exercise as well as a decrease in the metabolic rate along with muscle blood lactic reductions during the exercise in hot ambient or temperate circumstances (37). Although the precise mechanism is not clear, the proposed theories include increased blood flow to the skin, leading to decreased venous returns to the heart and carbon monoxide build-up in the system, thus, reducing cardiac output that perfuses the muscle. Another possible mechanism involves changes in muscle fiber activity from primarily oxidative to glycolytic fiber.

Guy et al., (2015) (38) reported that HA is vital for athletes competing in hot conditions. Another study indicated that the time to exhaustion and time-trial performance improved by ~23% and ~7%, respectively, after HA (39). These changes could be attributed to rises in maximum oxygen consumption (VO2 max; ~6%), lower lactate threshold (~1.0 mmol/kg), and thermotolerance among other adjustments. Enhanced thermal comfort can be a vital element associated with heat performance optimization by eliminating high-intensity exercise reservations that allow proper pacing during the competition (40, 41). Behavioral interventions to minimize dehydration caused by sweat further improve endurance efficiency (42, 43). HA was also shown to improve aerobic exercise in colder circumstances by 6% (29). Though, some studies observed no effect of HA (44, 45). Nevertheless, no evidence suggests that HA impairs aerobic performance under colder conditions, meaning that HA incorporated into annual training plans will likely boost performance under hot conditions without sacrificing higher-priority training goals (46). Physiological responses to heat acclimatization are summarized in Figure 2.

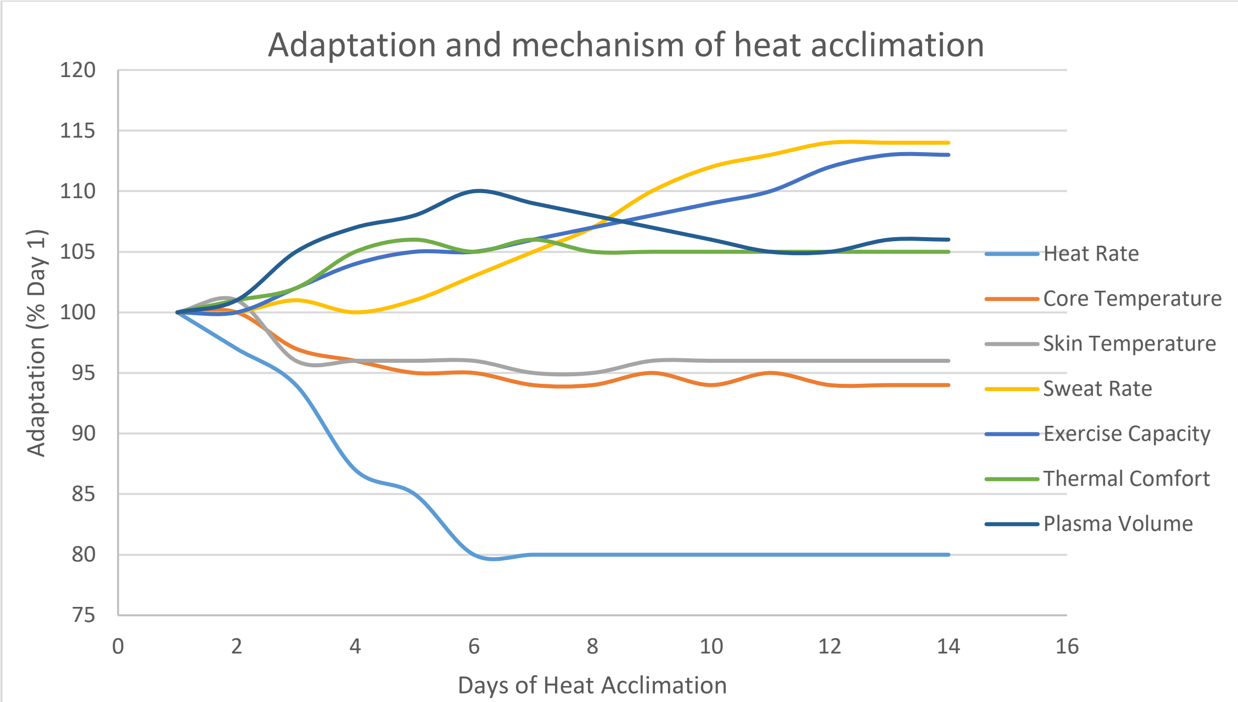

Figure 1. Illustration of the adaptation and the mechanism of HA (47, 48).

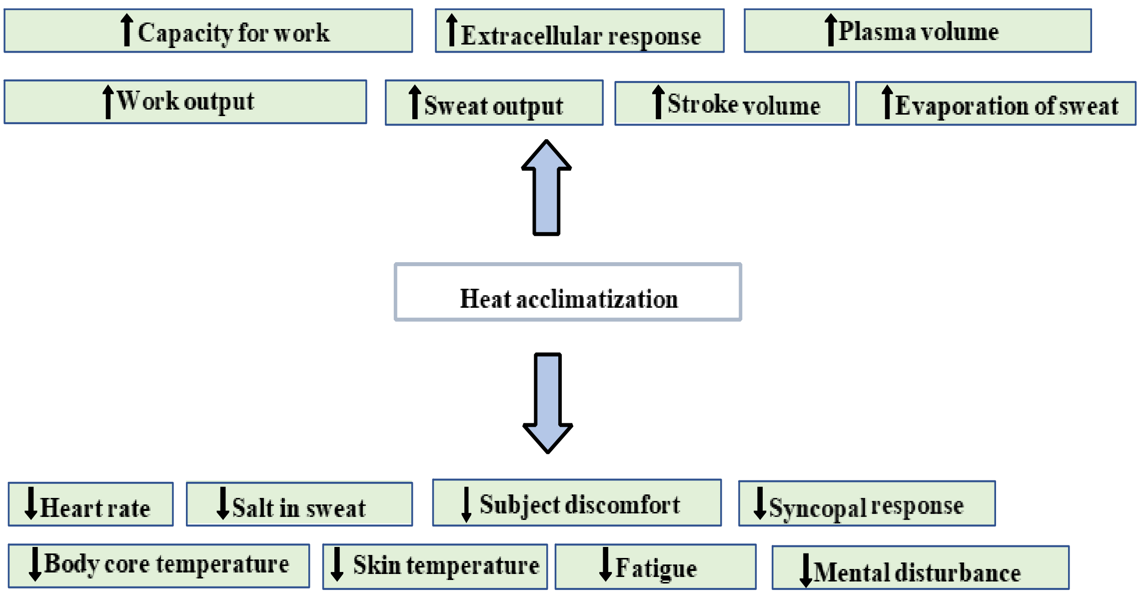

Figure 2. Physiological responses to heat acclimatization (10–14 days of exposure).

ADJUSTMENT CHALLENGES DURING SPORTS AND EXERCISE IN HEAT ENVIRONMENT

The scorching sun and stifling humidity are more than just inconveniences for athletes; they pose a significant threat to optimal exercise training and sports engagement. Across a wide spectrum of athletic activities, durations, and intensities, heat environments can severely impair performance (49). This disability manifests as an inability to sustain strength, power, speed, and endurance, ultimately leading to premature fatigue and a decline in sport-specific neuromotor skills (50). The culprit lies in a complex interplay between various physiological systems and mechanisms, each taking a hit from the heat's oppressive grip.

The cardiorespiratory system is one of the first to buckle under the heat's pressure. Heart rate skyrockets in an attempt to dissipate excess metabolic heat, while stroke volume and cardiac output plummet, leading to reduced blood flow to working muscles (51). This diminished perfusion further compromises oxygen delivery and energy substrate utilization, hindering metabolic efficiency and contributing to fatigue (25). Thermoregulation, the body's delicate dance of maintaining internal temperature, also gets thrown into disarray. Sweating, the primary cooling mechanism ramps up, but its effectiveness dwindles in humid environments, leaving the body struggling to shed heat. This internal battle diverts resources away from exercise performance, further sapping energy and focus (52). The impact of heat stress isn't limited to the physical realm; it extends to the mind as well. Psycho-cognitive function suffers, with increased perceived exertion, decreased motivation, and impaired decision-making hindering performance and potentially increasing the risk of injury (51).

The extent of these detrimental effects varies across sports disciplines. Endurance athletes, who rely heavily on sustained aerobic capacity, are particularly vulnerable to heat's debilitating effects (25). However, even short-duration, high-intensity activities like sprinting are not immune, with heat-induced fatigue and neuromuscular reductions compromising power output and explosiveness (53). Furthermore, the duration and intensity of exercise play a crucial role. As training sessions or competitions progress, the physiological strain accumulates, amplifying the negative impact of heat stress. Unsuitable training in extreme heat can lead to a cascade of problems, starting with dehydration and culminating in potentially life-threatening conditions like hyperthermia and heat exhaustion, especially during intense strength and power exercises (26, 53).

In conclusion, the heat is not merely a nuisance for athletes; it's a formidable opponent that can cripple performance across a wide range of sporting activities. Understanding the multifaceted impact of heat stress on various physiological and psychological systems is crucial for designing effective training strategies, ensuring optimal performance, and safeguarding the health and well-being of athletes in hot environments.

RECOMMENDATIONS

Event planners and managers should have the greatest possible infrastructure and amenities to reduce athletes' heat stress during the competitions which include the planning and recovery periods. Such initiatives include the provision of air-conditioned conference rooms and locker rooms for athletes and support for staff during the event. Readily available shaded areas to minimize total heat exposure, as well as cooling stations next to the competition site, are mandatory. A comprehensive emergency response plan with adequately trained personnel and the ability of on-site athletes to track full-body rapid cooling and body core temperature should be in place. Sports clothing and designs should place minimal restrictions on sweat evaporation, and the naked skin area available for evaporative heat loss should be maximized. Sportswear should set minimum sweat restrictions for evaporation, and protect the area of skin exposed for evaporation and the loss of heat should be minimized. Therefore, sports federations should consider likely heat and humid conditions when regulating their athletes' clothing styles for the competitions. An elaborate and inclusive approach that involves the coaches and training staff should be considered to plan adequately for the season especially when considering the negative impact of the humidity and heat conditions on the players to minimize the risk of heat exhaustion and to avoid medical complications. The rehydration approach, lifestyle adjustment, and HA plan are measures to be considered during the competition or tournament to prevent or reduce heat illness. Coaches should plan well for the type of exercise during the 14 days of acclimatization to improve body temperature and stimulate sweating without taking risks.

Acclimatization is shown to be most effective when the exercise duration is approximately 100 minutes. Intermittent exercise is likely to be as successful as continuous acclimatization exercise and is more likely to be accepted by sprinters and participants in a team sport, however, Maughan et al (54) documented that exercise at greater intensities for shorter periods might be effective in bringing about positive adaptations. 30 minutes per day at an intensity equivalent to around 75% of maximum oxygen uptake (V O2max) is effective as 60 minutes at 50% of VO2max.

For the most effective adaptation, the total exposure time, including short breaks, should probably be half a minute (55-57). Athletes need to drink more water or fluid when they are being acclimated to the heat to help in reducing sweat. If dehydration occurs and enhanced heat tolerance capacity fails, acclimatization would be affected, and the player might perform below expectations.

CONCLUSION

HA is a biological adaptation that minimizes physiological stress (e.g., heart rate and body temperatures), improves comfort, increases exercise capacity, and lowers the risk of major heat illness when exposed to heat stress. Hence, adequate HA can improve heat tolerance and increase the intensity or duration of work performed in the heat environment as well as reduce heat exhaustion and heat illness. Trainers, coaches, and players can use a variety of methods and recommendations to help them induce effective HE before any sporting event.

APPLICABLE REMARKS

- Heat acclimatisation is an avenue for athletes in competitive sports in hot environments to understand and improve their performance, reduce the risk of heat-induced illness, and even improve better quality of athletes lives. Sports federations and trainers should encourage athletes to participate in HA programs to avail them of quality adaptation and know the dos and don'ts of the program. Hence, HA programs should include gradual exposure to hot environments, both with and without exercise.

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AUTHORS' CONTRIBUTIONS

Study concept and design: Sameer Badri Al-mhanna, Alexios Batrakoulis, Hafeez Abiola Afolabi. Acquisition of data: Sameer Badri Al-mhanna. Analysis and interpretation of data: Bishir Daku Abubakar, Abdulhafeez Babalola. Drafting the manuscript: Faisal F. Saffah, Sameer Badri Al-mhanna, Bishir Daku Abubakar. Critical revision of the manuscript for important intellectual content: Wan syaheedah wan ghazali, Mahaneem Mohamed. Administrative, technical, and material support: Mehmet Gülü. Study supervision: Wan syaheedah wan ghazali, Mahaneem Mohamed, Bishir Daku Abubakar, Georgian Badicu.

CONFLICT OF INTEREST

No potential conflict of interest was reported by the authors.

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