Environmental Conditions

SSE #65: Preparing Athletes for Competition in the Heat: Developing an Effective Acclimization Strategy

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PREPARING ATHLETES FOR COMPETITION IN THE HEAT:
DEVELOPING AN EFFECTIVE ACCLIMIZATION STRATEGY
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KEY POINTS

1. Heat and dehydration can be an athlete's fiercest competitors.
2. Heat exposure and dehydration impair performance, and their negative effects are additive.
3. Acclimatization will reduce the negative impact of heat on athletic performance.
4. Acclimatization is most effectively achieved by exercise in the heat; heat without exercise and exercise without heat are less effective.
5. Acclimatization can be carried out by exercising in a hot room or by training in a hot climate.
6. The major physiological adjustments to heat acclimatization take about 7-14 days.
7. Training volume and intensity should be reduced on first exposure to the heat and then gradually increased. Some high-intensity training should be maintained throughout the acclimatization period.
8. Reducing the intensity and duration of the warm-up may be necessary to keep core temperature from rising too high before training and competing in the heat.
9. Monitoring responses of individual athletes is essential -- individuals respond differently to physical activity in the heat.
10. Records of body mass, urine output and color, and subjective symptoms should be kept by athletes and reviewed periodically by coaches and trainers.
11. Acclimatization increases the athlete's need for fluid to match the increase in sweat rate.
12. Dehydration impairs performance and negates the beneficial effects of acclimatization.
13. An adequate intake of an appropriate fluid before, during, and after training and competition is essential to ensure an optimal response to exercise in the heat.

INTRODUCTION

From a physiological standpoint, the most severe stress an athlete can encounter is exercise in the heat. The fact that many major sporting events are held in unfavorable environmental conditions makes it imperative that coaches and their support staff appreciate the severity of this challenge and understand how to effectively acclimatize their athletes for competition in the heat. Exercise performance is almost invariably impaired during hot weather, and at worst, the heat imposes a serious threat to the athlete's health. The history of major championship marathon races held in hot weather provides many examples of serious heat illness, including Dorando Pietri in the 1908 Olympic marathon in London, Jim Peters at the Empire Games marathon in Vancouver in 1954, and Gabrielle Andersen-Schiess at the 1984 Los Angeles Olympic marathon. Athletes in shorter running events and in sports such as rugby, soccer, and American football have also fallen prey to the heat. The common feature in the majority of these instances was the high ambient temperature. Athletes who are used to living, training and competing in temperate climates are placed at a significant disadvantage when an event is scheduled for hot, humid conditions, and a training strategy must be implemented to minimize this disadvantage.

The information in this Sports Science Exchange is gleaned from the scientific literature and from experience gained with British athletes at training camps held in Tallahassee, Florida, prior to the 1996 Atlanta Olympic Games. These training camps were deemed critical because of the adverse environmental conditions that were expected in Atlanta.

Exercise in the Heat

About 75% of the energy turnover during exercise is wasted as heat, inevitably causing body temperature to rise. In cool environments, much of this body heat can readily be transferred to the air (Nadel, 1988), but when the environmental temperature exceeds skin temperature, heat is gained and body temperature can rise to dangerous levels. At high ambient temperatures when it is not excessively humid, the only effective means of heat loss is by the evaporation of sweat secreted onto the skin. The evaporation of sweat is effective in dissipating large amounts of heat and will limit the rise in core temperature to no more than 3-4°C in all but the most extreme conditions of heat and humidity.

The physiological response to exercise in the heat is determined in part by the intensity of the exercise and in part by the degree of heat stress. At the same power output, exercise in the heat results in a higher heart rate and a higher cardiac output, as well as higher core and skin temperatures, compared with the same exercise in a cooler environment (Rowell, 1983). Exercise in the heat is usually accompanied by a higher blood lactate concentration, and there is some evidence of a faster rate of depletion of muscle glycogen. These cardiovascular and metabolic alterations are accompanied by a greater subjective sensation of effort in the heat, and a reduced exercise capacity.

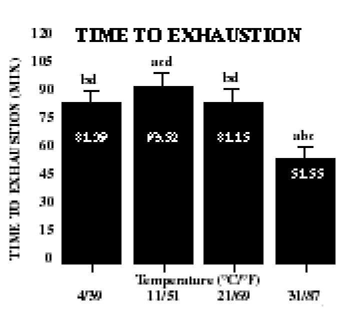

Figure 1. Time to exhaustion under four environmental conditions. Note that there is optimum environmental temperature for exercise performance.

Performance in all endurance events-which we define as those lasting longer than about

20-30 min-is reduced under conditions of heat stress, and there is no way of avoiding some impairment of performance. A study under laboratory conditions (Figure 1) showed that endurance time on a bicycle ergometer at an exercise intensity that could be sustained for 94 min at an air temperature of 11°C was reduced to 81 min when the air temperature was increased to 21°C and to 52 min when the temperature was increased to 31°C (Galloway & Maughan, 1995). In the conditions prevailing at the 1996 Atlanta Olympics and at many other sporting events, the reduction in performance would be even greater. It is recommended that hard exercise should not be undertaken when temperature and humidity are high (Figure 2), but major sporting events are seldom canceled even when environmental conditions are extreme. If the athlete is dehydrated before exercise begins, the reduction in performance that is observed in the heat is greatly magnified. It is likely that many competitors in events of shorter duration will also suffer from the heat, although the impact of adverse climatic conditions can be reduced by careful attention to acclimitization and fluid intake.

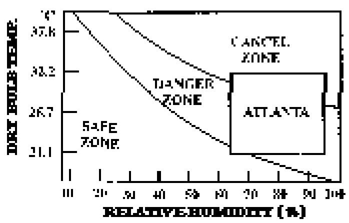

Figure 2. The combination of ambient temperature and humidity dictates environmental heat stress. Typical environment conditions in Atlanta in 1996 demonstrates the severity of heat stress encountered by athletes.

Competitors in indoor events might expect to suffer less, as these venues are often air conditioned. This should not, however, engender a feeling of security because competitors in indoor events are also at risk from the effects of heat and humidity. Exposure to heat even without exercise may result in a variety of symptoms, including headache, nausea, dizziness, and a sensation of fatigue (Wenger, 1988). Some exposure to hot conditions is inevitable, and in the hours when competitors are exposed to the local climatic conditions they are likely to become dehydrated, with adverse effects on performance, even in relatively cool indoor conditions and even when the exercise duration is relatively short. In one laboratory study, where dehydration equivalent to 2.5% of body weight was induced prior to exercise by sauna exposure, a 30% reduction in power output occurred in a test (which was conducted in cool conditions) lasting only about 7 min (Nielsen et al., 1982). Another carefully controlled experiment, carried out under race conditions, showed that 1500-meter runners ran 3.7% slower when they were dehydrated by 2% of body weight prior to exercise; 3.7% represents 6 seconds at world-class, 1500-m pace (Armstrong et al., 1985).

To minimize the adverse impact of hot, humid conditions, the coaching and training staff must address three issues: 1) a rehydration strategy, 2) an acclimatization strategy, and 3) lifestyle issues. This paper will focus on the second of these issues.

Responses to Heat Acclimatization
Regular exposure to hot, humid conditions causes a number of physiological adaptations that serve to reduce the adverse effects on exercise performance and lessen the risk of heat injury. Such responses include an increase in blood volume and an enhanced ability

to sweat. The increase in blood volume helps assure that the body can meet the demand for blood supply by both muscles and skin. Acclimatization also results in a faster onset of sweating, a greater distribution of sweat over the body, and an increase in the sweat rate. In addition, the sodium content of sweat tends to be reduced with acclimatization as the body attempts to retain sodium to help conserve extracellular fluid volume.

The rate of adaptation to physical activity in the heat depends upon the intensity and duration of exercise and on the environmental conditions. Some physiological adaptations can occur within the first few days of training in the heat so that even a few sessions of exercise in the heat can be beneficial (Lind & Bass, 1963). Most physiological adaptations to heat stress occur within about 7-14 days of regular exercise in a hot environment. Consequently, there may be no advantage of living for prolonged periods in a hot climate (Montain et al., 1996). It is equally clear that regular endurance training in temperate conditions confers some protection (Piwonka et al., 1965); trained subjects are already partially adapted to heat stress, although we do not know how complete this process is for highly trained Olympic athletes. The endurance athlete who trains wearing extra clothing to increase sweating during training in a cool climate will also show some degree of heat acclimatization, but this can be further enhanced by training in the heat (Dawson, 1994).

There is no doubt that acclimatization is necessary if athletes are to achieve optimum performance in hot, humid conditions. Acclimatization becomes even more important when athletes must compete more than once in a single day. The benefits conferred by acclimatization should neither be underestimated nor ignored.

Preparing for Competition in the Heat

There are two ways of acclimatizing for competition in the heat. One is to live and train in a climate similar to that expected at the competition venue. The other approach is to live at home and acclimate by training in an artificial climate. There are positive and negative aspects to both approaches. Because exercise capacity is reduced so much in the heat, training intensity and volume must be reduced for at least the first few days of the acclimatization process. This effect may be minimized if the athlete lives at home and is exposed to heat only during training, or during one of two daily training sessions, allowing some high-intensity training to be continued in the other session. If two training sessions per day are carried out, whether at home or in a hot-weather camp, it seems sensible for the high-intensity session to be done first, with the longer heat acclimatization session coming later in the day. The high-intensity training session should be in the cool outdoor air if conducted at home; if at a hot-weather venue, such training should occur in the early morning while it is still cool.

If the heat-acclimatization training is conducted during one of two sessions per day, the athlete is generally happier if the heat training can be gradually phased in, beginning with short (perhaps 30-60 min) sessions at low intensity. It is not necessary to train every day in the heat, but no more than 2-3 days should elapse between exposures. It has been shown that exercising in the heat every third day for 30 days resulted in the same degree of acclimatization as exercising every day for 10 days (Fein et al, 1975). For subjects who are well acclimatized, some of the improved responses are still present after as long as 21 days in a cool climate (Pichan et al., 1985). Athletes who train at home can introduce the heat acclimation sessions gradually while continuing with normal training.

A disadvantage of training in a hot room is that the exercise may be restricted to cycle-ergometer exercise, treadmill running, rope skipping, or circuit training. However, for acclimatization to the heat, the type of exercise is not important, provided that a period of prolonged (60-100 min), moderately strenuous exercise is carried out in hot conditions. The intention of the training session should be to raise body temperature and stimulate sweating without putting the athlete at unnecessary risk. There is evidence that acclimatization is most effectively achieved when the duration of exercise is about 100 min; there is no advantage in spending longer periods than this exposed to heat (Lind & Bass, 1963). Intermittent exercise is likely to be as effective as continuous exercise in stimulating acclimatization. The total exposure time, including short breaks, should probably also be 100 min for the most effective adaptation. It is also possible that exercise at higher intensities for a shorter period of time may be equally effective in bringing about beneficial adaptations; even 30 min per day at an intensity equal to about 75% of maximum oxygen uptake (VO2max) is as effective as 60 min at 50% of VO2max (Houmard et al., 1990).

If acclimatization is carried out at a hot-weather camp, information on local weather patterns is essential. For example, in Tallahassee, Florida, the temperature is highest near the middle of the day, with humidity being highest in the early morning and late afternoon. As a result, the training program for British athletes preparing for the Atlanta games was modified to take into account the prevailing conditions. When a high-intensity training session was required, the athletes trained in the cooler times of the day.

The timescale for training should be sufficient to allow for a few days (at least 3-4, but perhaps as many as 5-10 days) of reduced training during the heat of the day. In this case, both total training volume and the amount of training at high intensity should be reduced, the extent of the reduction depending on how the athletes respond. Because of the effects of heat, training for the first few days should be conducted at low intensity for a relatively brief duration, progressively increasing in volume and intensity as the athlete adapts to the new environment. It must be stressed that the extent and duration of the period of reduced training will vary among individuals. Normal training can resume for a few days while the acclimatization process continues and before tapering for competition begins. High-intensity training can continue, with enhanced periods of rest and recovery, over the final week before competition. Recovery will be faster and more complete if it is possible for the athlete to recover in a cool area. The coach must be alert to warning signs in those athletes having difficulty in coping with the adaptation process. Heat acclimatization generally requires at least 10-14 days, but a longer or shorter period may be appropriate for some athletes.

An ideal approach to acclimatizing athletes to the heat may be a combination of increasing the level of heat exposure at home during the last 1-2 weeks before traveling and a well-designed heat-acclimatization program at the new site. This might be of particular benefit to those athletes most at risk, i.e., those whose sports will result in the greatest exposure to the heat and those who have been found by experience to have difficulty in coping with the heat. It is strongly recommended that the coach make use of opportunities to experience hot, humid weather so that athletes who encounter problems can be identified and an effective acclimatization strategy devised. The acclimatization process requires the athlete to be exposed to sufficient heat stress for the necessary adaptations to take place, but there is a real danger that taking the process too far or too quickly can result in heat injury.

Modifying training sessions during hot weather

Both the warm-up and the training session must be modified during hot-weather training. For example, in a cool environment, the purpose of the warm-up is to elevate body temperature and increase blood flow to the muscles and connective tissues. In hot climates, the body temperature should not be markedly increased during the warm-up due to the very real possibility of reduced performance because of hyperthermia and dehydration. In explosive events of short duration, this advice may be disregarded, but where exercise continues for more than 2-3 minutes, body temperature should not be markedly increased before exercise begins. The coach, athlete, and trainer should consider modifications to the warm-up to ensure that this is achieved without compromising physiological and psychological preparation. It is absolutely essential that the modified warm-up protocol is practiced well in advance so that the athlete is comfortable with any changes that are made.

Basic modifications to the warm-up and subsequent training can include exercising in the shade, reducing the intensity and duration of the warm-up, removing any unnecessary protective equipment and clothing, and drinking plenty of fluids. Rest breaks should be longer and given more often, with athletes encouraged to recover in the shade or to take advantage of the cooling effect of fans. Rest breaks are also excellent opportunities to ingest fluid, an absolute must to assure optimal acclimatization.

Although athletes may be tempted to believe that the need for fluid replacement will decrease as they become adjusted to the heat, heat acclimatization will actually increase the requirement for fluid replacement because of the enhanced sweating response. Athletes have to drink more as they become acclimatized to the heat to help offset the increase in sweat rate that accompanies acclimatization. If dehydration is allowed to occur, the improved ability to tolerate heat that results from the acclimatization process will be compromised (Sawka & Pandolf 1990). There is no way to adapt to dehydration; attempting to do so is futile and dangerous.

Monitoring the athletes' responses to heat acclimatization
Some monitoring of individual responses to heat stress and of the rate and extent of adaptation is an essential part of preparation for competition in the heat. Training camps and other hot-weather opportunities should be used to collect information on individual athletes. Measurements made on individual athletes are a crucial part of the education process in demonstrating the adverse effects of dehydration and hyperthermia and in helping athletes understand how these effects can be minimized.

When exposed to the heat, athletes often become dehydrated despite the availability of fluids. Regular monitoring of body mass can give useful information on the athlete's hydration status, provided some precautions are observed. However, these records of body mass only have value if they can be compared with baseline measurements made in normal training conditions at home. All individual athletes must know their own optimum body weights for training and competing and how much their body weights normally vary on a daily basis. Body mass measurements should always be made at the same time of day, under the same conditions. Ideally, this will be done first thing in the morning, before breakfast or training, but after a visit to the toilet. If this is not possible, it may be done before training each day. Measurement of weight loss during training sessions should also be monitored so these measurements can be combined and compared with the normal daily pattern. A progressive decrease in body mass over the course of a few days is likely an indication of dehydration. Alternatively, longer-term weight loss could also be due to a loss of appetite and decreased food intake, a common response to hot conditions.

Athletes should be encouraged to keep a record of subjective symptoms associated with travel, training, and competition, to make note of the patterns that may emerge. This diary might record, in addition to daily body mass, some information on urine output, e.g., the time of day urine is passed, an estimate of the urine volume with a measuring cylinder, and the urine color (by comparison with a color chart). This information only has value if it is collected in hot conditions and can be compared with the normal pattern established over a period of at least a few weeks of training in a cool environment. Coaches and support staff have a responsibility to ensure that athletes appreciate the need to collect this information by explaining its value in advance. They must also keep an eye on the individual records and pay particular attention to anyone who appears to be having difficulty coping with training.

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