

Environmental Conditions

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EXERCISE PERFORMANCE IN THE HEAT

By Mark Hargreaves, Ph.D. Department of Physiology, The University of Melbourne.

Increases in environmental temperature pose a major challenge to athletes who must train and compete under such conditions. Exercise performance is reduced when the environmental temperature is increased from 20C to 40C. A small increase in heat load imposed by an increase in temperature from 3C to 20C is enough to result in a small, but significant, reduction in performance.

What limits exercise performance in the heat?

The rise in body temperature during exercise is determined by the rate of energy expenditure (i.e., the speed of running/cycling) and the environmental temperature.

During exercise in the heat, the increase in environmental temperature causes a reduction in heat loss and hyperthermia develops. It is not uncommon for body temperature to reach values of 40-41C following strenuous exercise in the heat and even under mild conditions, it can rise to very high values if exercise is hard enough. The major mechanism for the dissipation of heat is the evaporation of sweat, which requires an increase in blood flow to the skin and results in the loss of body water and electrolytes in sweat. Sweat losses have the potential to impair cardiovascular function and cause dehydration, which will further compromise the ability to dissipate heat and accelerate the rise in core temperature.

The hyperthermia that develops during exercise in the heat is a major factor in limiting performance. It has been suggested, for example, that at a critically high core temperature the

drive for exercise may be diminished due to negative effects on the motor centres in the brain. Hyperthermia has also been shown to increase the rate of muscle and liver glycogen breakdown during exercise. It is well recognised that carbohydrate depletion (low muscle glycogen) is a potential cause of fatigue during exercise. However, at the point of fatigue in the heat, muscle glycogen levels are relatively high suggesting that this may not be a major factor causing fatigue. Nevertheless, athletes who train in

hot conditions should ensure their diet contains sufficient carbohydrate to allow for the increased carbohydrate utilisation that occurs during exercise in the heat.

Another consequence of hyperthermia during exercise in the heat is an increase in temperature within the contracting skeletal muscles. This is likely to have negative effects on electrolyte distribution across the muscle membrane, calcium release and re-uptake and mitochondrial function. The ability of the muscles to maintain force and power output during exercise under such conditions may well be compromised.

Thus, hyperthermia appears to be a critical determinant of exercise performance in the heat. For this reason, strategies that minimise the rise in core temperature during exercise in the heat are likely to be effective in enhancing exercise performance. Acclimatisation to heat will reduce the rise in body temperature and improve tolerance to heat stress. Ensuring adequate hydration prior to and during exercise has been shown to enhance performance in heat. Finally, it may be worthwhile to consider pre-cooling as a means of reducing the absolute core temperature attained during exercise in the heat and thereby improving exercise tolerance.

The warning signs of dehydration include:

- Fatigue
- Loss of appetite
- Flushed skin
- Heat intolerance
- Light headedness
- Dark urine with strong odour

KEY POINTS

In summary, exercise in the heat results in major alterations in circulatory, thermoregulatory and metabolic function. The crucial factor limiting exercise performance appears to be the degree of hyperthermia that develops during exercise.

Controlling the rise in body core temperature during exercise in the heat may be an effective means of enhancing performance.

Successful hydration strategy requires that:

1. Coaches, athletes and support personnel are made aware of the benefits of adequate fluid replacement.
2. Appropriate fluid replacement strategies are developed and implemented.
3. Athletes have the opportunity to train themselves to ingest larger volumes of

fluid more frequently.

4. Other practical steps are taken to keep athletes cool during both training and competition.

Strategies to achieve this might include:

- Acclimatisation
- Fluid Ingestion
- Pre-cooling

Chairman's Column

Dear Reader,

In just a few months the eyes of the world will be on Atlanta, USA for the celebrations of the centenary Olympics. The competition for medals will be tougher than ever before not only because the present generation of Olympians are better prepared but because they will have to contend with severe environmental conditions. Atlanta in July is hot and humid and no place for the athlete who is out to achieve a lifetime best performance. One of the world's best marathon runners will not be in Atlanta chasing a gold medal because he is only too aware of what the heat does to his performance. Vincent Rousseau is the only runner to have broken 2h 08min twice for the marathon and knows himself so well that he will not even try to compete if the temperature goes above 15C (65F). If all marathon runners behaved in the same way as this Belgian athlete then the Olympics and most world championships would only be held in cool climates or during winter months. However, acclimatisation to exercise in hot and humid environments does occur when the appropriate preparation is undertaken. Dehydration is the athlete's enemy during exercise in hot and humid environments and the decrease in performance is predictable with every litre of sweat lost. Nevertheless, a significant decrease in performance can be prevented when athletes pay close attention to their fluid intake before and during exercise in hot and humid environments. This was the theme at an International Conference in Nottingham, England last November which provided the audience with the science behind temperature regulation during exercise in the heat. In this issue of Sports Science Update there are a selection of articles on dehydration and exercise performance in the heat written by several of the world authorities on this topic who contributed to the success of the Nottingham conference. The advice they offer has been tried and tested not only in the laboratory but also in the heat of competition. Following the advice offered by the GSSI Board members will help you or your athletes prevent the poor performance so frequently associated with competition in hot climates. Even if you are not competing in the Olympics your performance this summer will benefit from following the simple guidelines offered in this edition of Sports Science Update.

Clyde Williams
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PREVENTING DEHYDRATION AND HYPERTHERMIA

By Robert Murray, Ph.D., Gatorade Exercise Physiology Laboratory.

The combination of heat stress, dehydration and exercise imposes perhaps the most severe physiological challenge for the human body short of disease or serious bleeding.

Exercise in the heat requires the body to attempt to cope simultaneously with competing demands for cardiovascular homeostasis, thermoregulatory control and maintenance of muscle energetics. When dehydration is superimposed upon this scenario (as is often the case during most forms of exercise) the results can be catastrophic for both health and performance.

Fluid replacement reduces the risk of heat illness and improves exercise performance by preventing or reducing dehydration and by providing a convenient means of ingesting carbohydrate. The fact that even low levels of dehydration (e.g., equivalent to less than a 2% loss of body weight) impairs cardiovascular and thermoregulatory response, and reduces the athlete's capacity for exercise, is beyond scientific dispute.

For these reasons, optimal performance is possible only when dehydration is minimised by ingesting ample volumes of fluid during exercise. Recent research has demonstrated that consuming fluid in direct proportion to sweat loss (or close to it) maintains important physiological functions and significantly improves exercise performance, even during exercise lasting only one hour. Preventing dehydration enables the cardiovascular system to maintain blood pressure and cardiac output, thereby sustaining the increase in skin blood flow and sweating that are essential for optimal temperature regulation. Remaining well hydrated during exercise also preserves muscle function, reducing the reliance on muscle glycogen as a fuel source.

Carbohydrate ingestion also improves exercise performance, an effect that is independent of, and additive to, preventing dehydration. The practical application of this knowledge requires that athletes follow a more aggressive fluid replacement regimen than is now usually the case.

Success in the Atlanta Olympic Games will go to those athletes who are well acclimatised to training and competing in the heat and who diligently avoid even low levels of dehydration.

The competitive advantage will shift in favour of those athletes whose coaches and trainers recognise the fundamental value of fitness, acclimatisation and hydration, coupled with other strategies for keeping athletes cooled and fueled.

HEAT ACCLIMATISATION

By John R. Sutton, M.D., Dsc., Faculty Health Sciences, University of Sydney.

When athletes compete in the Atlanta Olympics in July 1996, those that do well will be able to ply their art best under extremely difficult thermal conditions that will prevail i.e. excessive temperature and humidity.

The Atlanta Olympics will prove to be particularly difficult for many involved in prolonged activities, especially the endurance sports - 5-10 km and the marathon. In order to perform well under these circumstances it will be vital for athletes to become acclimatised to these conditions. It may well be that those athletes who are very familiar with the hot and humid climates will excel.

What is Heat Acclimatisation?

Heat acclimatisation is the adaptations that the body undergoes in response to repeated exposure to a given set of environmental conditions of high temperature and/or humidity. In essence, acclimatisation results in the body being able to perform well under those conditions of stress so that with acclimatisation the body in fact undergoes less strain. An acclimatised individual therefore will find a specific task easier to perform and this comes about because;

- sweating will be greater
- sweating will begin earlier and at a lower core temperature
- the sweat will contain less sodium i.e. sodium will be conserved

All of these physiological functions then result in less strain on the body and so a given work level will be performed at a lower body core temperature and at a lower heart rate and with a lower perception of effort.

How Can This Be Achieved?

Heat acclimatisation is a relatively rapid process and can be achieved in about 8-15 days. Some of the adaptations, such as a decrease in heart rate will occur early on between 3-6 days, the sweat rate will probably increase optimally at about 10-15 days and similarly the sweat sodium concentration will decrease in that sort of time interval. The net effect of this is to decrease the body temperature at about the same time interval as the heart rate.

While most of those processes of heat acclimatisation occur in that short time frame it may well require many more weeks to get optimal acclimatisation.

In summary heat acclimatisation:

- Has a proven physiological basis
- Is desirable for all athletes and essential for all endurance athletes
- Is wise for officials (and spectators)

- Is reversible once gained can easily be lost
- Has an optimal timing - 15-30 days prior to the event
- While the natural environment may be preferred, acclimation in a thermal chamber is effective.

Acclimatisation versus Acclimation?

Acclimatisation refers to the natural phenomenon where individuals compete or exercise in a given environment and make the adaptations. Acclimation by contrast is achieved in an artificial environment such as a thermal chamber.

It should be noted, however, that from a physiological point of view the body does not make any distinction between these two processes, hence it is totally possible for an acclimated person to be as well adapted to perform in a hot humid environment as an acclimatised person.

What About Athletes from Cold Climates?

Athletes from cold climates clearly are not naturally acclimatised. For them to perform well in Atlanta a period of at least 2-3 weeks acclimatising would be recommended. Not only is it important to acclimatise but of course this must be put into the time frame where tapering will occur before an event.

Apart from all this it is vital to keep healthy, well rested, sensibly clothed and well hydrated, both in training and during competition.

TEAM SPORTS - PROBLEMS AND SOLUTIONS

By Dr. Mary Nevill, Department of Physical Education, Sports Science and Recreation Management, Loughborough University.

In the Barcelona Olympics in 1992 it was not uncommon for field hockey and soccer matches to be played in environmental temperatures of between 30 and 35C with relative humidities of 50 - 70%.

It is anticipated that the conditions in Atlanta 1996 could be even worse and the humidity may be higher than in Barcelona. An increase in humidity will decrease the evaporation of sweat and thus slow down heat loss.

Such environmental conditions pose tremendous problems for players in team sports, not least, because of the very nature of the sporting activity itself.

PROBLEMS RELATING TO THE NATURE OF THE GAME:

- 70-90 minutes + warm up + extra time
- Demanding intermittent activity (average exercise intensity 70-

80% V_{O2}max)

- Approx. 7 games in 10-14 days
- Recovery as short as 24 hours
- Difficulty in taking fluid during play (usually only possible during stoppages)
- Recent changes in rules to speed up the game (e.g. removal of the obstruction rule in hockey, no stoppages for injuries in soccer)
- Individual variations in physique and fitness amongst players within a squad with skill being a key factor in selection.

The physiological problems faced by the players in such conditions are generally presumed to be similar to those faced by athletes performing in prolonged endurance events. Such problems are inter-related and are summarised in the following section.

Physiological strain of performing prolonged exercise in heat

Hyperthermia ~ In laboratory experiments subjects tend to become exhausted at approximately the same body temperature of (about) 39C, regardless of acclimation status; these high body temperatures will be reached earlier when the athlete is dehydrated.

Dehydration ~ Voluntary rehydration may only cover 50% of fluid losses and

researchers have shown that as little as 4% reduction in body mass will cause a 30% reduction in endurance performance in temperate conditions, but a 50% decrease in performance in the heat.

Carbohydrate Availability ~ The rate of muscle glycogen degradation is enhanced in the heat and when dehydrated.

Recently the development of new laboratory and field-based tests have allowed physiologists to examine more closely the physiological strain of, and the decrement in performance during, the activity patterns found in team games.

For example, when male games players performed only 30 minutes of intermittent cycle ergometer exercise, sprint performance was decreased at 35C, but remained unchanged at 10C. Furthermore, when the subjects were asked to cycle to exhaustion at the end of the intermittent test at maximal intensity they could only exercise for 82s in the heat in comparison with almost 300s in a cool environment.

In another experiment involving intermittent walking, jogging, striding and sprint running performed for 70-90 minutes in a gymnasium, the total distance completed was reduced from 11200m at 20C to only 8800m at 30C. Interestingly in this field-based test where fluid was readily available, despite the very high exercise intensity and the running activity, team players doubled their intake from 0.6 to 1.2 litres per hour. Therefore, in the real game situation where it is more difficult to drink the decrements in performance may be even greater.

So how can team players prepare for performance in the heat and humidity and attempt to reduce their

performance decrement? The weight of available evidence strategies suggests the following possible answers.

STRATEGIES TO ENHANCE TEAM GAME PERFORMANCE IN HEAT HUMIDITY

Endurance training

- will lower the %VO₂ max for a given exercise
- results in larger and more sensitive sweat glands
- will slow the rate of rise in body temperature
- will elicit many of the benefits of acclimation.

Acclimatisation

- should be commenced early
- should focus on individual differences (see article by Prof. Sutton p.4).

Prevent Dehydration

- focus on meals which will, increase sodium intake and enhance voluntary rehydraton and fluid absorption in the small intestine
- increase protein intake which may enhance the rate of muscle glycogen resynthesis
- provide fluids
- check body weight regularly
- check that the urinre is pale in colour
- sleep and rest in a cool environment.

Cool Players

- **try to keep the pre-game body temperature low by reducing the length of the warm-up and/or lowering the exercise intensity**
- **cool players at half time and during substitutions.**
- **pay attention to clothing**

Playing Strategy

- consider a change in strategy to lower the exercise intensity at which the game is played.

CONCLUSION

The physiological strain induced in games players by performing in hot and humid climates is at least as great as that experienced by athletes performing in endurance events.

Both the amount of background running in a game and performance during longer sprints will be affected. The decrements in performance can be reduced by following sensible guidelines relating to dehydration, diet, training, acclimation and by modifying warm-up procedures. However, as the decrements in performance are unlikely to be totally removed, the coach and team should also consider the possibility of changing the strategy to reduce the exercise intensity and thus the physiological and thermal strain on players in these conditions.

Editors note;

Mary Nevill was captain of the British Hockey Team who won a bronze medal at the 1992 Barcelona

Olympic Games.

ASK THE INSTITUTE

The Gatorade Sports Science Institute (GSSI) was created to foster education, service, and research in sports nutrition, exercise science and sports medicine.

Q I have heard that athletes should not snack but rather stick to three meals per day. Is this a good idea?

A Snacking is an important part of an athlete's nutrition programme and will help to restore energy levels quickly. Refuelling between sessions will be enhanced if you eat carbohydrate on a regular basis. This will inevitably mean including some snacks in your daily routine. Variety is the key to successful snacking and these snacks should not replace balanced meals. Alternate your favourite biscuits/cake/chocolate or crisp snack with other choices to ensure that you maintain a healthy sports diet. A snack before training will help to boost energy levels, particularly before long, hard workouts. Some ideas for snack choices include toast, cereals, crumpets, English muffins, bagels, current buns, pancakes, dried fruit, energy bars, honey / jam / banana sandwiches, scones or bananas.

If you are becoming really tired between sessions then top up your carbohydrate levels with an extra boost from jams / honey / confectionery / cakes / biscuits / sports drinks.

These foods are not as bulky as some of the ideas above. If you cannot tolerate food then use drinks to speed up the refuelling process.

Peggy Wellington, British Olympic Association Sports Nutritionist, UK.

Q Is aerobic training important for athletes competing in sprint events?

A During a sprint event the athlete is required to cover a relatively short distance in the shortest possible time. The metabolic energy to support such high rates of muscular effort comes predominantly from anaerobic mechanisms (glycolysis and creatine phosphate breakdown), with a relatively small contribution from aerobic metabolism. Thus, at a first glance, it would seem that it is not so important to do any aerobic training to improve performance during sprint competition.

However, the situation is different during sprint training sessions when the athlete is required to perform repeated sprints interspersed with relatively short recovery intervals, and the aim is to recover fast and get ready for another quality repetition. Research suggests that endurance training helps muscles to recover faster from lactic acidosis and to resynthesise creatine phosphate at an enhanced rate by increasing the number of capillaries and providing more oxygen to the recovering muscles. As a result, the muscle's energy systems are better prepared to face the next sprint and more work is produced. Indeed, our research has shown that there is a high correlation between endurance fitness, creatine phosphate resynthesis and the recovery of sprint performance. In addition, the contribution to energy supply from aerobic energy sources is increased with every repeated sprint and can reach considerably high levels. This would suggest that a high aerobic power (VO₂ max) may be important during repeated sprint training.

It appears, therefore, that sprinters should not underestimate the potential benefits of aerobic training, since an increase in training quality will improve sprint performance during competition.

Gregory C. Bogdanis, Ph.D., Human Performance Centre of Athens, Greece

**If you have any questions, please write to: SPORTS SCIENCE UPDATE,
GSSI Europe, P.O. Box 262, Slough, SL3 8FL, UK - marking your envelope "Ask The Institute".**

We regret we cannot provide individual answers to every question received. We will attempt, however, to ensure that answers are provided in subsequent issues. Questions may be combined or modified.