Physical Solutions
Physiotherapy, Functional Training and Education

Exercising in the Heat

Mad dogs and Englishman go out in the midday sun " when Noel Coward wrote these words in 1930 he was referring to the English percant for attempting to work during the middle of the day with the heat at it's most intense. The difficulties of attempting to work and play during the hottest temperatures is well recognised in hot climates and reflected in the long standing tradition of siestas. Unfortunately today's athletes do not have that luxury, sports and politics are inextricably linked and a multimillion pound industry. Witness the relentless campaigning for the Olympic games or the next world cup. Competitions are increasing held in countries during the hottest months of the year with time zones and television contracts requiring athletes perform when the heat is at it's most intense.

When the 1996 summer Olympic games were awarded to Atlanta, Georgia it was immediately recognised that athletes would encounter severe climatic conditions. Daytime temperatures were expected to reach 31 c and average relative humidity around 69%(Gleeson et al 1995)(Maughan 1997) posing problems for outdoor endurance events and potential of severely reduced performance (Sawka 1992). In situations such as these athletes who live and train and are used to competing in temperate climates will be placed at a distinct disadvantage. However adaptation is possible, repeated exposure to exercise in the heat can produce acclimatisation (Nielsen 1998), changes in physiological function by which the tolerance to heat stress are improved.

To understand acclimatisation, it is firstly imperative to realise the physiological, thermoregulatory, and metabolic responses of the body to exercise, and the consequences of external heat. There are closely interrelated factors that will limit exercise performance, insufficient metabolic substrates and oxygen delivery, inability to maintain adequate cardiac output, electrolyte and fluid imbalance, acid base disturbances and hyperthermia. Although relatively efficient the bodies' metabolic processes result in heat production. As physical exercise increases total body metabolic rate to provide energy for contracting muscle heat production will increase. The 70%-75% of metabolism lost as heat will drive up the body temperature (Sawka 1992)(Maughan Shirreffs 1997) and will need to be dissipated to avoid potentially dangerous high body temperatures. Work by Sawka et al 1992 has determined core temperature of 40 c as the extreme upper limit before heat strain can occur.

To attenuate this rise, increases in core temperatures are sensed by receptors in the central nervous system, conveyed to the hypothalamus, which evokes heat loss mechanisms of increased skin blood flow and increased sweating rate. Sweating is an effective way to maintain stable core temperatures and the amount lost during intense exercise in hot conditions may exceed 3 l/h

(Nielsen 1996). Sweat rate is determined primarily by exercise intensity, ambient temperature, and humidity although variations exist between individuals under the same conditions (Maughan, Sherriffs 1996).

This losses can represent significant reductions in body weight bearing in mind that water is the largest component of the human body between 45%-70% (Sawka 1992), and decreases of 4%-6% body weight have been reported during soccer (cited Maughan, Sherreffs 1997 in Maughan, Leiper 1994). Uncompensated fluid loss has physiological effects that can result in hyperthermia. Eccrine sweat is hypotonic to plasma so plasma osmolality is seen to increase, studies by Montain and Coyle 1992 found high correlation's between increasing serum osmolality and increases inbody temperature.

Concurrently reductions in blood volume result in a mechanism known as "cardiovascular drift". The reduced central venous pressure and subsequent cardiac filling would result in reduced stroke volume, therefore to maintain cardiac output an expedient heart rate is required. If fluid loss continues unabated the body is eventually faced with a dichotomy, maintain peripheral blood flow to ensure heat loss or shut down peripheral perfusion to conserve adequate cardiac output to the brain and vital organs. The metabolic demands will take precedence over thermoregulatory mechanisms and continued exercise would result in severe hyperthermia and potentially death.

Without necessarily reaching such extreme and life threatening positions, dehydration of even 1% body weight can induce cardiovascular strain during exercise, limit heat loss via sweating and importantly for the athlete impair performance (A.C.S.M) 1996)(Sawka 1992). Therefore the importance of fluid replacement during exercise is unequivocal, and supported by several studies. Montain and Coyle 1992, report fluid ingestion maintains a high skin blood flow and reduces hyperthermia during the 2nd hour of cycling Bt preventing increases in serum osmolality. Hamilton et al 1991 reported fluid replacement during exercise could prevent the decline in stroke volume, and again as exercise continued into the 2nd hour, result in an increased cardiac output and prevention of hyperthermia. These physiological benefits also translate to improved performance, Barr et al in 1991, demonstrated no fluid replacement during 6 hrs of exercise in the heat led to subjects terminating the trial on average after 4.5hrs, while with fluid replacement completing the trial. Equally during 1hr cycling in the heat at 80% vo2 max, Below et al 1995, demonstrated fluid replacement improved performance in time by 6%.

In recent years knowing the importance of fluid replacement has led to the investigation of the optimum solution, and can be witnessed in the rapid growth of "sports drinks". Along with water loss through sweating there is also an excretion of electrolytes, mainly sodium and chloride. Actual amounts and composition of sweat is difficult to determine due to large biological variations and effects of training and acclimatisation, however typical values for sodium are in the range of 20-80 mmols L (Maughan and Sherreffs 1997). Replacing fluids from just pure water can result in the dilution of the plasma concentration of sodium. This can have the effect of stimulating urine production and blunting the sodium dependant stimulation of thirst (Aoyagi et al 1997). To prevent hyponatraemia and its effects fluid replacement should contain approximately 50 mmols L of sodium and possibly some potassium.

In prolonged exercise glycogen depletion is well documented as a mechanism for peripheral fatigue (Coggan and Coyle 1987). It therefore follows that the addition of carbohydrate during exercise may spare reserves and prolong performance. Other benefits are reported by Hamilton et al 1991, demonstrating infusion of glucose and water prevented an increase in VO2 and cardiovascular drift, and Below et al 1995 who showed fluid and carbohydrate ingestion improved performance.

Often during competition it is not practical or feasible to consume a meal to obtain carbohydrates thereby necessitating their addition to the fluid replacement. Carbohydrate and electrolyte solutions however must be kept below 10%(g.100ml of fluid). Excessive concentrations will result in a net movement of fluid into the intestinal lumen by the nature of their high osmolality and in effect could increase dehydration (Noakes et al 1991). Solutions with carbohydrate concentrations below 10% can promote uptake by maintaining an osmotic gradient. To ingest the beneficial amount of 30-60g an hour (A.C.S.M 1996) required during moderate to high intensity exercise concurrent fluid ingestion would have to occur (Gleeson et al 1996).

In order to achieve the necessary nutrients to improve performance and deter fatigue, the carbohydrate content of ingested solution has been stated previously as an important regulator of gastric emptying. Gastric emptying has therefore been seen as the limiting factor for the ingested fluids (Costill and Saltin 1974), however this premise is addressed by Noakes et al 1991 who believe other factors influence delivery. Initial studies on gastric emptying focused on absorption after a single volume of fluid was ingested, however work by Rehrer et al 1990 (cited by Noakes et al 1991) found repeated “topping up” of fluids after the initial ingestion increased the percentage of gastric volume emptied during subsequent 20 minute intervals. Thereby volume may be the most important factor in determining emptying rate and beneficial to those athletes who can maintain a “full fluid load”.

To summate the importance of fluid replacement the A.C.S.M position stand (1996) recommends consuming adequate fluids during the 24h period before an event and 500ml 2hr before exercise, ensure fluid replacement equals fluid loss, and in exercise over 1-hr carbohydrates and electrolytes should be added to the beverage.

Although maintaining adequate fluid replacement is off vital importance when exercising in the heat further benefits can be achieved and performance enhanced by effective acclimatisation. Acclimatisation refers to the functional compensations made of several of exposure to the totality of a challenging new environment (Aoyagi et al 1997). In effect the body undergoes less strain when performing in conditions of stress.

The physiological mechanisms responsible for the bodies enhanced ability to cope with exercise in the heat after acclimatisation, include better maintaince in blood volume, changes in sweat production, reductions in heart rate and core temperature, and alterations in substrate utilisation.

An increase in plasma volume may be mediated by protein influx into the intramuscular space and sodium conservation (Werner 1992). This will assist in maintenance of cardiac output and prevention of cardiovascular drift. There is noted to be a faster onset of sweating, greater distribution of sweat over the body and increase in sweat rate. It has been reported that the increased sensitivity of the sweat glands for thermal and hormonal stimuli after acclimatisation may be obtained through an increase in receptor density for neural and humeral stimuli, and an increase in the size or in the number of active sweat glands (Nielsen 1988).

Kirwan et al (1987), found a reduced use of muscle glycogen following heat acclimation and were supported by Febbraio et al (1994), who observed reductions in blood glucose, blood lactate, and type 1 fibre glycogen utilisation. These adaptations post acclimatisation were thought to be mediated by observed changes in plasma epinephrine concentrations.

When advising athletes on acclimatisation they should be aware that the beneficial adaptations can occur over a relatively short period of time, changes develop over a few days and are essentially complete after 14 days (Aoyagi et al 1997, Gleeson et al 1995, Maughan 1997). This is achieved by spending about 60 –100 min/day exercising in hot conditions similar to those that will be encounted during competition. Each exposure must be sufficient to raise the core temperature a substantial amount and provoke moderate to profuse sweating. An example for an endurance athlete may involve moderate to vigorous exercise at 75% vo2 max, in 40-50c temperatures 60-120 min/day over 1-2 weeks. Another factor would be to mimic the humidity level expected albeit dry or wet heat.

The athlete need not relocate to a climatic location similar to the one expected. An artificial climate can be utilised in a home environment and allows for a more settled and familiar environment, however the practical application will limit the type of exercise that can be performed. Initial training should be done at a reduced intensity and duration to avoid heat illness and gradually expanded as the majority of physiological adjustments occur in 4-6 days (Pandolf 1998). Further practical advice for the athlete would be to avoid excessive warm ups as body temperature will already be markedly higher, partake in frequent rest breaks in cooler environments, wear appropriate clothing to aid in heat dissipation, and ensure adequate fluid replacement due to the increased activity of the sweat glands.

Potential problems and dehydration should be monitored for by regular measurements of the athlete. These include daily weighing at the same time, body mass measurements, and urine output and colour. If this becomes routine potential problems can be anticipated and corrected to maintain the well being of the athlete.

This report has attempted to explain the physiological consequences on the body while exercising in the heat. Dehydration can lead to heat exhaustion and potentially heat stroke, a medical emergency requiring immediate attention. Recreational and elite athletes alike need to be made fully aware of the importance of fluid replacement, and provision for this in the form of fluid stations, and cooling areas made available particularly in endurance events. When travelling to compete the benefits of an effective acclimatisation period have been well documented and Olympic athletes cannot afford to waste 4 years of training due to inadequate preparation. Although nowadays it is often only “mad dogs and athletes that go out in the midday sun” with the proper advice at least they should be safe!

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