How to cool a 'hot brain'

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It is well known that dehydration affects the body's sporting performance, but just how does dehydration affect the brain's performance? Did you know that dehydration of only a 1.8 per cent or 2 per cent decrease in body weight can impair exercise performance and have powerful negative effects on the brain and muscles? Dr Shi explains how we can cool a hot brain.

How does the brain get ‘hot’?

The human body consists of 45–75 per cent fluid, with leaner people having the higher values. Many organs of the body are primarily water, for example:

- blood contains 75 per cent water
- muscle contains 78 per cent water
- the brain contains 92 per cent water.

During exercise, working muscles produce a large amount of heat and core temperature rises as a result. To effectively regulate body temperature and prevent heat injury, the evaporation of sweat is the primary way for heat loss during exercise. Athletes can easily sweat a litre per hour during exercise and each litre of sweat can remove approximately 580 kcal of heat via evaporation. However, we pay a price for the cooling benefits of sweat if lost fluids are not properly replaced. That price is dehydration and it has negative effects on cardiovascular and thermoregulatory function. One such effect is hyperthermia (high body temperature). During hyperthermia, the body core temperature can sometimes rise to over 40°C (Cabanac 1993) and exert a big impact on the brain as well. Dehydration and hyperthermia have powerful negative effects on the brain and muscles. Studies have shown that dehydration during exercise impairs exercise performance (Armstrong et al. 1985; Buskirk et al. 1958; Craig and Cummings 1966; Dengel et al. 1992; Olsen and Saltin 1976; Barr et al. 1991). This impairment can be observed with dehydration of only 1.8 per cent (Walsh et al. 1994) or 2 per cent (Saltin and Costill 1988) decrease in body weight.
How does heat affect the brain?

Human brain cells are heat sensitive and among the most susceptible to dehydration. It is no surprise that dehydration can impair reaction time, judgment, concentration, decision-making and mental clarity. This reduction in mental performance becomes significant with a 2 per cent body weight loss (Gopinathan et al. 1988; Sharma et al. 1986).

Studies have shown that during exercise or heat exposure (Gopinathan et al. 1988; Sharma et al. 1986; Cian et al. 2000) dehydration can induce a reduction in various cognitive abilities involving short-term memory, working memory, or visuo-motor abilities. Short-term memory can be tested by memorising a complete string of digits after each digit is presented for one second. Visuo-motor ability is the ability to make fast and correct connections from visual recognition to motor action. Working memory is the cognitive system that allows us to keep active a limited amount of information for a brief period of time. The dehydration and heat-induced impairments of cognitive function during exercise might affect the development of physical skills and overall performance (Cian et al. 2001). Since the reduction in mental performance is proportionate to the degree of dehydration (Gopinathan et al. 1988), it is critical for coaches and athletes to understand that dehydration is harmful for both physical and mental performance; the more severe the dehydration, the worse the performance.

How does dehydration impair mental performance?

It has been shown that cortisol, one of the stress hormones released during exercise and heat exposure, causes memory function to decrease (Kirschbaum et al. 1996). By logical extension, it is possible that an increased cortisol level induced by dehydration might cause a reduction in cognitive abilities. In addition, the hyperthermia-induced reduction in brain blood flow could potentially impair the delivery of substrates like glucose as well as the removal of metabolites (Nybo et al. 2002) and also interfere with cognitive abilities. It is also known that dehydration can occur with hypoglycemia (low blood glucose) during prolonged exercise. Blood glucose is an important energy source for muscles and an indispensable energy source for the brain (Pardridge 1983). Continuously supplying glucose to the brain can help prevent a failure of the central nervous system in providing an optimal neural drive to the contracting skeletal muscles. In other words, an adequate glucose supply to the brain helps prevent premature fatigue.

Maintaining blood glucose can:

- help maintain central nervous system function, including reduced perception of fatigue, reduced risk of negative mood states, and maintained cognitive function (Pardridge 1983; Amiel 1998; Cox et al. 1993; Utter et al. 1999)
- delay the onset of central fatigue by helping maintain the balance of neurotransmitters in the brain (Bequet et al. 2001).

How can the ‘hot brain’ be avoided?

Science shows that the replacement of fluid, carbohydrate and electrolytes during exercise can:

- restore crucial body fluids
- maintain normal cardiovascular functions
- prevent or delay physical and mental fatigue
- enhance exercise performance.

A study (Montain and Coyle 1992) investigating the effects of graded dehydration on hyperthermia and cardiovascular function during exercise had the subjects ingest no fluid, or small, moderate, or large volumes of fluid to replace what was lost in sweat. The data showed that greater dehydration resulted in greater increases in core temperature and heart rate and a larger decline in stroke volume, all of which would negatively affect performance. Another study (Below et al. 1995) compared the effects of no fluid replacement, carbohydrate ingestion, fluid ingestion, and carbohydrate plus fluid ingestion on exercise performance during one hour of intense
exercise. The scientists found that fluid and carbohydrate replacement enhanced performance, with fluid plus carbohydrate (such as a sports drink) providing the best overall performance.

The importance of carbohydrate availability in the brain in preventing fatigue has been demonstrated by glucose infusion directly into the carotid artery in exercising dogs (Koslowski et al. 1981). Sports drink ingestion by athletes during practices and competitions provides a benefit to the muscles as well as the brain (Davis et al. 1992). Moreover, recent studies (Nybo 2003; Welsh et al. 2002) have reported that carbohydrate feedings result in a 37 per cent longer run time, improve motor skill test performance, and maintain central nervous system activation during stop-and-go activity.

Summary

Dehydration and hyperthermia can impair physical performance and mental abilities such as reaction time, judgment, concentration, decision-making, and also some cognitive abilities. Keeping the athlete's body cooled and fuelled is the best way to keep muscles and brain functioning at levels that result in improved performance.

Practical tips

- Drink enough during exercise to minimise loss of body weight.
- Favour a sports drink over water during practices and competition.
- Prepare for hot-weather exercise by gradually building training intensity and duration over a week or two.
- During intense training in the heat, take frequent rest breaks in the shade to help the body shed heat.
- When possible, reduce the amount of clothing and equipment worn during hot-weather exercise.

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References


