dDehydration and its effects on performance

This is an excerpt from [Sport Nutrition, Second Edition], by Asker Jeukendrup, PhD, and Michael Gleeson, PhD.

Fatigue toward the end of a prolonged sporting event may result as much from dehydration as from fuel substrate depletion. Exercise performance is impaired when an individual is dehydrated by as little as 2% of body weight. Losses in excess of 5% of body weight can decrease the capacity for work by about 30% (Armstrong et al. 1985; Craig and Cummings 1966; Maughan 1991; Sawka and Pandolf 1990).

Sprint athletes are generally less concerned about the effects of dehydration than are endurance athletes. However, the capacity to perform high-intensity exercise, which results in exhaustion within a few minutes, is reduced by as much as 45% by prior dehydration corresponding to a loss of only 2.5% of body weight (Sawka, Young, Cadarette, et al. 1985). Although sprint events offer little opportunity for sweat loss, athletes who travel to compete in hot climates are likely to experience acute dehydration, which persists for several days and may be serious enough to have a detrimental effect on performance in competition.

Even in cool laboratory conditions, maximal aerobic power (.VO2max) decreases by about 5% when persons experience fluid losses equivalent to 3% of body mass or more, as is shown in figure 8.6 (Pinchan et al. 1988). In hot conditions, similar water deficits can cause a larger decrease in .VO2max. The endurance capacity during incremental exercise is decreased by marginal dehydration (fluid loss of 1% to 2% of body weight), even if water deficits do not actually result in a decrease in .VO2max. Endurance capacity is impaired much more in hot environments than in cool conditions, which implies that impaired thermoregulation is an important causal factor in the reduced exercise performance associated with a body-water deficit. Dehydration also impairs endurance exercise performance. Fluid loss equivalent to 2% of body mass induced by a diuretic drug (furosemide) caused running performance at 1,500, 5,000, and 10,000 m distances to be impaired (Armstrong et al. 1985). Running performance was impaired more at the longer distances (by approximately 5% at 5,000 and 10,000 m) compared with the shortest distance (approximately 3% at 1,500 m).

A study investigated the capacity of eight subjects to perform treadmill walking (at 25% .VO2max with a target time of 140 minutes) in very hot, dry conditions (49° C [120° F], 20% relative humidity) when they were euhydrated and when they were dehydrated by a 3%, 5%, or 7% loss of body mass (Sawka, Young, Francescone, et al. 1985). All eight subjects were able to complete 140 minutes walking when euhydrated and 3% dehydrated. Seven subjects completed the walk when 5% dehydrated, but when dehydrated by 7%, six subjects stopped walking after an average of only 64 minutes. Thus, even for relatively low-intensity exercise, dehydration clearly increases the incidence of exhaustion from heat strain. Sawka et al. (1992) had subjects walk to exhaustion at 47% .VO2max in the same environmental conditions as their previous study. Subjects were euhydrated and dehydrated to a loss of 8% of each individual’s total-body water. Dehydration reduced exercise endurance time from 121 minutes to 55 minutes. Dehydration also appeared to reduce the core temperature a person could tolerate, as core temperature at exhaustion was about 0.4° C (0.7° F) lower in the dehydrated state.

The main reasons dehydration has an adverse effect on exercise performance can be summarized as follows:

• Reduction in blood volume
• Decreased skin blood flow
• Decreased sweat rate
• Decreased heat dissipation
• Increased core temperature
• Increased rate of muscle glycogen use

A reduced maximal cardiac output (i.e., the highest pumping capacity of the heart that can be achieved during exercise) is the most likely physiologic mechanism whereby dehydration decreases a person's VO2max and impairs work capacity in fatiguing exercise of an incremental nature. Dehydration causes a fall in plasma volume both at rest and during exercise, and a decreased blood volume increases blood thickness (viscosity), lowers central venous pressure, and reduces venous return of blood to the heart. During maximal exercise, these changes can decrease the filling of the heart during diastole (the phase of the cardiac cycle when the heart is relaxed and is filling with blood before the next contraction), hence, reducing stroke volume and cardiac output. Also, during exercise in the heat, the opening up of the skin blood vessels reduces the proportion of the cardiac output available to the working muscles.

Even for normally hydrated (euhydrated) individuals, climatic heat stress alone decreases .VO2max by about 7%. Thus, both environmental heat stress and dehydration can act independently to limit cardiac output and blood delivery to the active muscles during high-intensity exercise. Dehydration also impairs the body's ability to lose heat. Both sweat rate and skin blood flow are lower at the same core temperature for the dehydrated compared with the euhydrated state (see figure 8.4) (Nadel et al. 1979 1980; Sawka and Wenger 1988). Body temperature rises faster during exercise when the body is dehydrated. The reduced sweating response in the dehydrated state is probably mediated through the effects of both a fall in blood volume (hypovolemia) and elevated plasma osmolarity (i.e., dissolved salt concentration) on hypothalamic neurons. As explained previously, as core temperature rises towards about 39.5° C (103° F), sensations of fatigue ensue. This critical temperature is reached more quickly in the dehydrated state.

Dehydration not only elevates core temperature responses but also negates the thermoregulatory advantages conferred by high aerobic fitness and heat acclimatization. Heat acclimation lowered core temperature responses when subjects were euhydrated. However, when they were dehydrated, similar core temperature responses were observed for both unacclimated and acclimated states (Pinchan et al. 1988).

A person's ability to tolerate heat strain appears to be impaired when dehydrated, so the critical temperature for experiencing central fatigue is likely to be nearer 39.0° C (102.2° F) when dehydrated by more than about 5% of body mass (Sawka et al. 1992). The larger rise in core temperature during exercise in the dehydrated state is associated with a bigger catecholamine response, and these effects may lead to increased rates of glycogen breakdown in the exercising muscle, which, in turn, may contribute to earlier onset of fatigue in prolonged exercise.