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**The Effects of Dehydration on Cognitive Functioning, Mood, and Physical Performance**

**Molly Hodges**

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It is no surprise to most everyone that the human life depends tremendously on a compound composed of two Hydrogen atoms and an Oxygen atom: water. Water is such a huge component of the human life; it comprises 75% of the body weight in infants, 55% in the elderly and is crucial for cellular homeostasis (Popkin 439). In fact without water humans can only survive two to four days (Daniels 505). In a moderately brief period of time, failure to consume enough water will lead to deteriorating neurologic function, organ failure, and ultimately death (Lieberman 1-5555). Failure to consume a proper amount of fluid has always been linked to such life threatening outcomes, but equally important is how dehydration affects the way one thinks, feels, and is able to perform. Each of these are important aspects of life, in that these very components shape the human life. Most research has led to the notion that the inability to take in and maintain the necessary amount of water can lead to impaired cognitive functions, disturbed emotional states, and decreased physical performance.

**DEHYDRATION AND COGNITION**

When an individual fails to ingest the appropriate amounts of fluid it leads to a condition known as dehydration. Dehydration refers to a loss of body water mainly from the intracellular compartments and a loss of extracellular fluid clinically affecting the vascular tree and interstitial compartment. Most use the term dehydration or hypohydration to refer to total body water loss or insufficient fluids (Thomas 292). Dehydration has been linked to a decline in mental processes known as cognitive functioning. Cognitive function is a process associated with several aspects of mental thinking, such as memory, psychomotor controls, attention, perception, executive thinking, and language skills. Several studies have confirmed that the inhibition of water also negatively affect cognition in several aspects such as short-term memory function, working memory capabilities, perceptive discrimination, and visual-motor function (D'Anci 458). Supporting these claims directly was a study that examined the effects of water deprivation on men and women. The results concluded that heat- and exercise-induced moderate acute dehydration of at least two percent of an individual's body weight resulted in a significant impairment in the specific areas of cognitive-motor functions dealing with short-term memory, working

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memory, perceptive discrimination, and visual-motor function (Szinnai R275). Other results from similar studies concluded that with dehydration, there was significant deterioration in total test solving time, minimum single task solving time, and total overall time (Petri 858).

### **EFFECTS OF LOWERED COGNITION**

Mental haziness that is created from lack of body fluid will affect an individual's ability to mentally perform to the best of their ability. Mental haziness is a term often used to describe a feeling of not being able to focus and having unclear thoughts. Decrements in physical, visuomotor, psychomotor, and cognitive performance can occur when two percent or more of body weight is lost due to water restriction, heat, and/or physical exertion (Grandjean 459S). This was measured through a study of subjects dehydrated by one to five percent of their body weight through heat, exercise, and absence of water. Several cognitive functions such as arithmetic efficiency, short and long term memory, and attention, showed impairment when the subject was dehydrated by at least two percent of their total body weight (Grandjean 459S). Mild dehydration has been seen to impair performance on tasks such as memory, perceptual discrimination, arithmetic ability, visuomotor tracking, and psychomotor skills (D'Anci 460).

Negative effects of dehydration on cognitive performance have been evident in some studies. It has been reported that a seemingly easy task becomes harder when an individual is hypohydrated, therefore an apparent effort to complete the task maybe required. In a study using functional magnetic resonance imaging 10 healthy adolescents, with a mean age  $16.81 \pm 0.49$  years and a body mass index  $66.1 \pm 9$  kg, completed a thermal exercise procedure and nonthermal exercise control condition in a cross-over repeated measures design (Kempton 71). The results showed that dehydration caused higher levels of perceived effort in many tasks, increased tiredness and difficulties in concentration. The findings in this study suggest that an increase in fatigue is overcome by an increase in fronto-parietal brain activation, which may be experienced by participants as giving a larger effort. One of the conclusions from the study indicated that dehydration does negatively impact brain functions underlying important cognitive processes, especially concentration, in young people as opposed to the adult population (Kempton 77).

### **DECLINE IN MENTAL PERFORMANCE**

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Since severe dehydration unavoidably leads to delirium, coma, and eventual death, there is no doubt that it will produce a decline in cognitive function before such brutal consequences occur (Liebermann 1- 5560). Disturbances in water homeostasis have shown to cause either a slight or severe decline in overall mental functioning, depending on level of hypohydration. In tasks that require high accuracy, perform under obligatory regime, allow for no mistakes, or involve sophisticated or potentially dangerous equipment, a deteriorated mental and psychomotor processing could potentially endanger overall performance and execution of tasks (Petri 856). There was evidence that dehydration to 2.7% body weight loss by heat exposure or exercise has been shown to drastically decrease alertness, concentration, tracking performance, increase tiredness and headaches in healthy young adults (Ritz S7). It also took dehydrated subjects a longer time to respond to questions (Ritz S7). The inability to adequately function cognitively can cause mild problems such as a bad test grade all the way to severe predicaments such as a factory worker being unable to concentrate on their task, leading to detrimental consequences.

Reintroduction of fluids under circumstances of mild dehydration can reasonably be expected to reverse dehydration-induced cognitive deficits (Popkin 446). One study examined how water ingestion affected awakening and cognitive performance in young people following a period of 12 hour water restriction. While cognitive performance was not seen to be greatly affected by either water restriction or water ingestion, water intake did affect self-reported arousal. Therefore in this study, testing did not necessarily indicate a difference in cognition, but the participants felt like they were doing better, which lends to the idea that hydration status consistently affected self-reported alertness, but effects on cognition were less consistent than in other studies (Popkin 447).

Researchers have pointed out the limitations in accurately measuring the effect of dehydration on cognitive functioning due to difficulty in assessing just one variable as the cause and the difficulty in distinguishing different levels of hydration (Liebermann 2- S35). It has been pointed out that measuring such a temperamental component as cognition is hard, especially when you are trying to base its decline or improvement on a variable like dehydration. Even so, there seems to be enough evidence supporting the claim the decreased hydration will in most cases lead to some degree of decreased level of cognitive functioning.

Alterations to cerebral blood flow and/or metabolism caused by decreased levels of hydration may also be important catalysts of fatigue during exercise in a warm environment (Maughan 604S). Dehydration especially coupled with physical exertion has been seen to cause a mental sedation and feelings of apathy (Kempton 77). By increasing fatigue, people tend to show

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more signs of lack of interest and low motivation, due to the feeling of extra strain when attempting even the simplest tasks. In most studies, although it is not a main concern of the experiment, fluid restriction is seen to have a noticeably negative effect on the subjects' perceived ability to function mentally and on their overall feeling of wellbeing (Sherriffs2 957). Dehydration can have a side effect of irritability and frustration because even simple tasks can seem to require more effort than usual. More technically, it has been suggested that dehydration, unlike other stressors, may create shifts in electrolytes that could substantially alter brain neurotransmission since neuronal function is highly dependent on the physiological setting of the central nervous system (Liebermann 1- 5559 ). With each study it is clear that dehydration induced by heat exposure, exercise, and fluid restriction impairs emotion (Liebermann 1-5614).

### **MOOD**

The lack of sufficient amounts of fluid can range from mild to severe, with increasingly dangerous clinical signs associated with each range. Basic clinical signs of dehydration include problems such as restlessness, decreased alertness, dizziness, lethargy, agitation, and confusion (D'Anci 460). These signs are directly correlated with altered emotional states, triggered by the lack of sufficient fluids.. One study showed that under conditions of mild dehydration with young adults, there were significantly higher scores for anger, confusion, and fatigue (D'Anci 460). The investigators deprived young male and female volunteers of all fluids for 28 hours and achieved a 2.6% mean body mass loss. Multiple tests of cognitive performance and mood were administered from 24 to 28 hours after the start of each session. Few alterations in cognitive performance were observed, but there were effects of dehydration on self-reported levels of tiredness, alertness, effort, and concentration and some evidence of an altered mood and cognitive performance decrements in females. The results of this study indicate that mood is more likely to be affected by modest levels of dehydration than cognitive performance and that women may be more sensitive to dehydration than men (Lieberman 2-S34).

### **HORMONAL FLUCTUATIONS**

There are several theories surrounding the phenomenon of women being more emotionally affected by dehydration, most all are centered on hormonal changes. One proposed theory that is still strongly hypothetical is

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that an influence of the natural variation of levels of luteinizing hormone, follicle-stimulating hormone, estrogen, and progesterone may offer some explanation (Szinnai R277). Luteinizing hormone and follicle stimulating hormone are gonadotropin hormones that stimulate the ovaries in females. Luteinizing hormone and follicle stimulating hormone are responsible for the stimulation and the maturation of follicles in the ovary and stimulates secretion of sex hormones, which are necessary for reproduction (Bowen 1). Estrogen and progesterone are also important female hormones that work together and are responsible for functions including but not limited to breast cell stimulation, maturation and development of secondary sex characteristics, fat cell storage, controlling libido, salt and fluid retention, normalizing blood clotting, and restraining bone loss (Lee 1). High levels of estrogen has been linked to improved memory and articulation, while in contrast, low estrogen has been associated with better visual spatial abilities. Osmotic sensibility varies with the menstrual cycle; therefore decreased cognition due to low estrogen values in female subjects in studies could be responsible for significant gender-dehydration interaction in reaction time-based response measures in certain cognition tests (Szinnai R278). Natural hormonal fluctuations is one reason it is hard to decipher if it is dehydration or just hormones causing mood disruptions, or if different levels of hydration may affect the increasing or decreasing presence of certain hormones.

Other mood altering factors include the changes in brain neurotransmission, in particular dopamine, which appears to be responsible for fatigue when exercising in the heat (Maughan 6045). Dopamine is a chemical messenger that affects brain processes that control movement, emotional response, and ability to experience pleasure and pain. Dopamine can greatly affect an individual's emotional states which can be seen in diseases where the brain releases too much, such as schizophrenia, and where it releases too little, such as in Parkinson's disease (Erikson). Although not widely researched, dopamine seems to be affected by dehydration which can lead an individual to experience mood swings (Erikson).

### **PHYSICAL PERFORMANCE**

Along with there being a decline in cognitive performance, there is also a severe impairment in physical performance that is caused by hypohydration. Peripheral factors, such as muscle glycogen depletion, can account for fatigue in endurance exercise in cool temperature environments, but not in the heat (Maughan 604S). Fluid ingestion during exercise can decrease the subjective sensation of fatigue and enhance performance when exercise lasts more than about 40 minutes (Maughan 604S). Dehydration has also shown to limit the

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aerobic and anaerobic components of exercise performance, which includes maximal oxygen uptake, anaerobic power output, and physical work capacity (Yoshida 529). During challenging athletic events, it is not uncommon for athletes to lose 6–10% of body weight through sweat, which inevitably leads to dehydration if fluids have not been replenished. When an individual loses approximately 4.8% water body mass loss there is a significant compromise in the ability to perform a resistance exercise bout (Judelson 1824). In fact it has been seen that starting with dehydration of around 4% of the body weight, a greater proportion of water loss comes from intracellular sources which could disrupt the electrochemical potential of the cell membrane and contribute to faster muscle fatigue (Yoshida 530). However, decline in the physical performance of athletes have been observed under much lower levels of dehydration (Popkin 444). Under relatively mild levels of dehydration, individuals engaging in demanding physical activity will experience a decrease in performance related to reduced endurance, increased fatigue, altered thermoregulatory capability, reduced motivation, and increased perceived effort. Studies suggest that hypohydration seems to have a more significant impact on high-intensity and endurance activity, such as tennis and long-distance running, than on anaerobic activities such as weight lifting, or on shorter-duration activities, such as rowing (Popkin 445).

One speculation for reduced performance is the reduced muscle size that can occur because of loss of fluid. One study concluded that if hypohydration in fact fails to reduce muscle force or power, that exercises such as the vertical jump height should actually increase as total body water decrease, because the jumper would have less mass to move (Judelson 1824).

This is only the case if the individual is able to overcome the increasing muscle and mental fatigue caused by dehydration in order to produce the same effort that they would have given prior to the hypohydration. Dehydration coupled with prolonged exercise has also seen to cause a decrease muscle glycogen by up to 16%. This increased muscle glycogen utilization in a dehydrated situation probably results from higher body temperatures, increased catecholamine levels, or a combination of the two (Shirreffs1 S17).

Other physical effects of dehydration that hinder physical performance is an increase in body temperature which makes the body have an increased perceived effort and ultimately have a harder time performing overall (Kempton 76). Also when body water content is decreased through total body dehydration, an increased heart rate and decreased stroke volume is observed, indicating an increased cardiovascular strain, meaning that the heart must work harder to try and maintain homeostasis, which in turn increases perceived effort (Shirreffs1 S16).

## **CLIMATE**

Dehydration effecting physical performance is mostly seen to be exacerbated by hot climates. Exercise in hot conditions with inadequate fluid replenishment is more seriously associated with hyperthermia, reduced stroke volume and cardiac output, decreased blood pressure, and reduced blood flow to muscle (Popkin 446). The effects of exercise intensity and heat load on deteriorating performance are connected; performance declines even before physiological responses are impaired and even highly motivated subjects are affected by heat load, especially when assigned to complex tasks that require a high level of attention, cooperation, and coordination (Grandjean 463S). Increase temperatures in effect create a high cerebral temperature which may lead to changes in motor drive that affect the capability to recruit adequate muscle fibers to meet the demands of exercise (Maughan 608S). In hot environments, 31- 32 degrees Celsius, the sweating rate is increased causing 60 minutes of intense exercise to elicit dehydration by approximately 2% of body weight, which has been seen to cause adverse effects (Coyle 40). In a study where participants were purposefully dehydrated and made to do several different exercise tasks in a warm climate, it was confirmed that hypohydrated individuals who completed isotonic, multiple-repetition, multiple-set, intermittent resistance exercise tasks will likely experience impaired performance (Judelson 1823). Dehydration by 2% of body mass during exercise in a hot environment (31°C–32°C) impairs endurance performance, but when exercise is performed in a temperate environment (20°C–21°C), dehydration by 2% of body mass appears to have a less significant effect on endurance performance (Shirreffs 1 S16). Such findings suggest that in less hot environments, dehydration by more than 2% may be tolerable but may also make the dehydration less noticeable and therefore possibly more dangerous. The overheating of the body's temperature is known as hyperthermia which has been seen to cause changes in the brain's electrical activity (Maughan 610S). The altered brain activity causes a reduction in the ability to maintain voluntary contractions and in turn creates an increase in perceived exertion (Maughan 610S).

## **CONCLUSION**

Performance of both physical and mental tasks is notably reduced by heat and dehydration (Maughan 604S). While most of the studies point out the difficulty in measuring variables based on dehydration, the research still concludes that aspects of cognitive functioning such as memory, perception,



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attention, and concentration are mostly negatively affected. Similarly, the mental and physical fatigues along with other factors, that lack of hydration produces, cause a decline in mood and physical performance. Most of the studies conducted around the effects of dehydration, suggest that deteriorated mental and psychomotor processing occurs early after the beginning of inadequate fluid consumption, pointing to the importance of a regular and perhaps planned regime of fluid intake (Petri 860). It is this evidence that continues to support the notion that inadequate fluid consumption not only can lead to seemingly obvious long term severe consequences but can also lead to immediate and mostly ignored negative effects.

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