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THE SCIENCE OF HYDRATION

This document provides an overview of the scientific literature related to the hydration needs of athletes.

INTRODUCTION

Approximately 50-60% of an adult's body weight is water. Body water plays an important role in numerous physiological processes such as excretion of wastes, blood volume and blood pressure regulation and transport of oxygen and nutrients to the brain and exercising muscles. Water also plays an important role in body temperature regulation by transferring heat. When an athlete exercises, heat is created within the body – sweating and the evaporation of sweat from the skin surface is the primary mechanism by which the body cools itself. Since water plays such a large role in the human body, and the loss of water through sweat is an important protective mechanism during exercise, it is important that athletes consume fluid to prevent significant hypo-hydration (~2-3% body mass deficit), helping them stay safe and perform at their best.[18]

PHASES OF THE HYDRATION PROCESS

Hydration is a process that starts with the ingestion of fluid, followed by emptying from the stomach and absorption through the intestines, then distribution of the fluid throughout the body and finally retention or excretion of the fluid by the kidneys.

Fluid Intake

The sensation of physiological thirst is stimulated by both a decrease in the amount of water in the blood (also called hypovolemia) and by increased plasma osmolality. Osmolality is the amount of dissolved particles, such as sodium or glucose, in the blood. Both hypovolemia and increased plasma osmolality occur during dehydration due to sweating. The perception of thirst can also be increased or decreased by signals arising from the mouth, throat and stomach. Other factors, unrelated to thirst and hydration status, can also affect how much fluid an athlete consumes. These include how much an athlete likes a beverage, availability, as well as social and cultural factors.[12]

Physiological thirst is not stimulated until the body is already dehydrated.[1,2,7] Thus, the threshold for thirst lags behind body hydration changes and therefore, lags behind true fluid needs. This can lead to voluntary dehydration, which means despite having access to cool, palatable fluid, athletes still dehydrate during exercise. Research shows that voluntary dehydration occurs not only in laboratory studies but also with athletes in the field, including endurance events and team sports.[11,13,14] While drinking to thirst may work for some athletes in some instances, a planned hydration strategy is recommended, particularly if an athlete may dehydrate by more than about 2-3% body weight.[18]

Fluid Absorption

The process of fluid absorption involves the emptying of fluid out of the stomach as well as transport across the intestinal wall. The rate at which these processes occur is important in order to avoid gastrointestinal distress and for rapid delivery of fluid to the body.

The rate of gastric emptying is controlled by numerous factors including beverage amount, beverage composition and exercise intensity. One of the more important factors is the amount of calories in the ingested beverage. Research has shown that a 6% carbohydrate solution (14 g/8 oz.) is emptied as quickly from the stomach as the same volume of water during exercise. However, increasing the carbohydrate concentration to 8% results in more of the beverage remaining in the stomach, leading to gastrointestinal distress and slower delivery of fluid to the body.[10,15]

The next step is intestinal fluid absorption. This process is dictated primarily by the amount and type of carbohydrate ingested. The absorption of water follows carbohydrate, so the rate of fluid absorption is inversely related to the concentration of carbohydrate. Small amounts of carbohydrate increase intestinal fluid absorption, while higher amounts decrease absorption. Inclusion of multiple types of carbohydrates (e.g. glucose and fructose) can improve fluid absorption by taking advantage of the different carbohydrate transporters found in the intestine.[16] For more information on multiple transportable carbohydrates, please see Sports Science Exchange #108 “Multiple Transportable Carbohydrates and Their Benefits” by Dr. Asker Jeukendrup, found at www.gssiweb.com.[8]

Fluid Distribution

Total body water can be divided into two compartments: the intracellular space, which includes water inside muscle and brain cells, and the extracellular space, which includes fluid in the space between cells and the plasma. In a 154-lb. person the amount of water inside the cells is about 28 L and the amount of water outside the cells is about 14 L. The balance of water inside and outside the cells is determined in part by sodium intake as well as other electrolytes such as potassium and chloride. Sodium is the primary extracellular electrolyte. When sodium is consumed, it is distributed to the fluid outside of the cells, so sodium intake during exercise helps maintain blood sodium concentration. Sodium ingestion also helps retain fluid in the blood, which is important for maintaining or expanding plasma volume for rehydration and cardiovascular function.

Fluid Retention

The presence of sodium in a fluid-replacement beverage is also important for whole-body fluid retention. For rehydration after exercise, the fluid consumed needs to stay in the body as opposed to being lost through urination. When plain water is consumed, blood sodium concentration is diluted, turning off the signal to the kidney to reabsorb water and resulting in increased urine volume. By contrast, when a sodium-containing beverage is consumed, blood sodium concentration is increased, which in turn stimulates the reabsorption of water in the kidneys so that less urine is formed. In fact, fluid retention increases in direct proportion to beverage sodium concentration.[9] Experts recommend that to achieve complete rehydration after exercise, athletes should consume a moderate- to high-sodium beverage in a volume equivalent to 150% of fluid loss. This extra fluid volume helps compensate for urine excreted during the rehydration process.[6] Drinking the beverage slowly over several hours, and adding carbohydrate and/or protein, will slow the rate of fluid update and further improve rehydration.[6]

DETERMINING HYDRATION NEEDS OF ATHLETES

Hydration guidelines have been developed based on the research around fluid intake, absorption, distribution and retention. These guidelines take into account the basic principles of hydration physiology as well as factors such as individual variation in fluid and sodium loss during exercise, training status and environment. Overall it is important for an athlete to begin exercise in a hydrated state, drink enough fluid with sodium during exercise to maintain body weight within about 2%, and rehydrate after exercise using fluid with sodium, in an amount slightly greater than body weight loss.[18] See Table 1 for specific recommendations.

It is important to note that for exercise lasting greater than 60 minutes, athletes need to not only consider hydration needs but carbohydrate as well. In some cases the emphasis may be greater on one or the other, but a sound sports nutrition plan will account for both hydration and fueling. For a team sport athlete, research has shown that a 6% carbohydrate solution (14 g per 8 oz.) will deliver energy to help meet the recommendation of 30-60 g/hour while entering the body as fast as water.[10] However, for endurance athletes exercising greater than ~2.5 hours have greater carbohydrate needs, more fuel can be delivered by using the right blend of carbohydrate, specifically a 2:1 blend of glucose and fructose.[8] Lastly, if an athlete chooses a solid carbohydrate source, adequate water should be consumed.

Athletes should monitor their urine color throughout the day, and before exercise strive for a light-yellow color. Urine specific gravity measurement can be used to estimate hydration status, with a value <1.020 indicating adequate hydration.[18] During exercise, an individualized fluid plan for an athlete can be developed based on body weight changes. The average athlete loses 1-2 L of fluid per hour of exercise, but sweat fluid losses can vary outside of this range.[5,18] Many factors impact sweat fluid and sweat electrolyte losses, including genetics, temperature, humidity, environment, equipment, as well as training status and intensity. Similarly, sweat electrolyte concentration varies greatly, the average range is anywhere from 260-1990 mg/L.[5] Ultimately, the total sodium losses will be impacted by the amount of fluid lost per hour and this is important to consider when putting together a hydration plan. The GSSI website (gssiweb.com) provides detailed instructions and a calculator to determine sweat fluid losses. This test should be conducted in the environment in which the athlete will compete, and repeated as the environment changes.

Historically, a straightforward assessment did not exist to assess sodium needs. If an athlete is a salty sweater, or white residue can be observed on their clothing, they may need higher sodium intakes during exercise or recovery.[18] More recently, a commercially available, validated, sweat patch is available for the assessment of sweating rate and sweat sodium losses.[3,4] The patch measures chloride concentration, which can be reasonable translated into sodium concentration.

TABLE 1: HYDRATION RECOMMENDATIONS FOR ATHLETES[17]

~4 hours Before Exercise	5-7 mL/kg fluid
~2 hours Before Exercise	3-5 mL/kg fluid *IF urine is dark or not produced
During Exercise	Fluid with sodium, amount based on body weight changes
After Exercise	20-24 oz. of fluid with sodium for every pound of body weight lost during exercise

DRINKING TO THIRST VS. A HYDRATION PLAN

At lower levels of dehydration, drinking when thirsty may be an appropriate approach for some athletes. However, thirst is affected by many factors that are not dependent on dehydration. Also, at the time an athlete is thirsty, they might not have access to fluids, there might not be a timeout in a basketball game or they may be between aid stations on the race course. Once an athlete reaches greater than ~3% dehydration, gastric emptying is impaired and drinking at that point may lead to gastrointestinal distress.[19] Developing a hydration plan allows the athlete to practice their strategy to help ensure they remain hydrated while focused on the competition.

Any opinions or scientific interpretations expressed in this document are those of the author and do not necessarily reflect the position or policy of PepsiCo, Inc.

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