# Hydration

Water constitutes a greater percentage of body mass than any other substance. It helps fill the spaces inside the cells, outside of the cells, and in all major vessels (Figure: The Purpose of H2O). Water is continually being formed and broken down in the major metabolic pathways of the body. Opinions concerning what (and how much) physically active individuals should drink vary greatly when coaching clients, and the advice given can be pivotal in improving performance and maintaining general health. It was not that long ago that American football coaches commonly treated players’ thirst as a sign of a lack of toughness (Dent, 1999). In contrast, a young American football player recently and tragically died from overconsumption of fluids following a routine practice.

The good news is that the overwhelming majority of clients do not need any hydration advice, because of the low volume of sweat loss experienced during typical training situations. However, there are scenarios in which hydration advice can be pivotal in helping clients optimize physical performance. This chapter will attempt to blend the basic science principles of hydration physiology and human performance with real-world application for the Nutrition Coach who is motivated to use contemporary research to develop optimal hydration strategies for a variety of physically active individuals.

Getting Technical

Hydration Strategy Guidelines

The first formal and widely disseminated guidelines for fluid intake were published by the American College of Sports Medicine (ACSM) in 1996 (Convertino et al., 1996). In the following two decades, knowledge of how water and electrolyte losses affect human performance has continued to expand. These new levels of insight have led to major revisions of the original policies created by the ACSM (Sawka et al., 2007).

Other influential organizations, such as the National Athletic Training Association (Casa et al., 2000; McDermott et al., 2017) and the International Marathon Medical Directors’ Association (Hew-Butler et al., 2005), have also created their own guidelines. Some of these guidelines present viewpoints that have considerable contrast, ranging from very-specific fluid recommendations to simply allowing thirst to dictate fluid intake (Beltrami, Hew-Butler, & Noakes, 2008; Cotter, Thornton, Lee, & Laursen, 2014; Noakes & Speedy, 2007). Making a concise and uniform hydration strategy is complicated by the nonuniformity in these guidelines and made more confusing by the discrepancies in suggestions offered by exercise science textbooks and popular, non-peer-reviewed reading sources such as fitness magazines.

Try This

How might a Nutrition Coach respond to the following situations? Record your responses now and see if they change after completing your reading about hydration.

Scenario 1: After refraining from working out for several years since high school, a friend tells you that a week of upper-body weightlifting has resulted in repeatedly dark urine color and very stiff and swollen elbow joints.

Scenario 2: A triathlete and member of your local endurance sport club has posted a picture of a very new and expensive road bike. Statements are made that the new bicycle is very light and also has five, 1-liter bottle holders!

Scenario 3: You are contacted by a NCAA Division I basketball’s strength-and-conditioning coach and told that the majority of the team frequently reports to practice with dark-colored urine and a urine-specific gravity (USG) reading above 1.020.

Scenario 4: You are training two clients. Their warm-up begins with jogging one lap around a track. After the first lap, one client exits to the infield and lies down on their back, appearing weak and breathing heavily. The other client runs to the aid of their training partner and immediately begins yelling, “We need water. She's dehydrated!”

A blue water drop with white text

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## The physiology of hydration

Water constitutes 50 to 70% of total body mass (Figure: Body Water Percentage). Under normal living conditions without heavy sweat losses from environmental or exercise stress, total body water fluctuates very little from day-to-day (Armstrong et al., 2010). Roughly 2/3 of this fluid is located inside of individual cells and is referred to as intracellular fluid (ICF). The majority of the remaining fluid can be found in the vascular system (plasma portion of blood) or in the space between cells (interstitial fluid). Collectively, the fluid found outside of cells is termed extracellular fluid (ECF) (Figure: ECF and ICF).

A person with water on their body

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While there are many solutes (e.g., glucose and red blood cells) located within the body’s water compartments, the primary factor that determines what space body water will occupy is dependent predominantly on the concentration of two electrolytes. The first is sodium (Na+), the major ECF solute, while the second is potassium (K+), the major ICF solute.

Getting Technical

You have probably heard that electrolytes are contained in sport beverages and are important for athletic performance. But what is an electrolyte? Electrolytes are molecules that contain a negative or positive charge. Notice the plus sign after the atomic symbol for sodium and potassium in the previous paragraph. The superscript plus symbol denotes that the molecules (in this case two minerals) are positively charged, meaning that each type of atom has one more positively charged proton than negatively charged electron.

The regulatory mechanism that describes the processes that dictate total body water levels and water compartment movement in the body is called osmolality.

The majority of fluid and electrolyte shifts in the body and between compartments are caused by three primary actions provided in the Figure: Involuntary Actions That Deplete Body Water and Electrolytes.

A diagram of a diagram of a health problem

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Water in the body continuously seeks to find a distribution in ICF and ECF spaces where the number of solutes in each compartment is roughly equivalent. Most solutes located in these spaces cannot freely cross the cell membrane barriers separating ECF and ICF, but water has a unique capability. With sodium being the primary ECF solute, its concentration is a primary factor in determining the amount of water that will enter a cell body (i.e., ICF) or remain in the ECF.

With an understanding of osmolality and the recognition that the only significant means to add water and electrolytes to the body is by food and beverage consumption, it is apparent that sodium intake is a pivotal dipsogenic signal when attempting to restore total body water after training.

Food for Thought

When large quantities of sodium are ingested without a similar increase in water, plasma osmolality increases and increased thirst drive follows (Johnson, 2007). Most athletes and coaches recognize that thirst is influenced by total body water. However, the most significant influence to thirst for water is regulated by ECF osmolality. Humans experiencing great total-body water losses will not naturally attempt to match sweat losses with fluid intake (Adolph, 1947). In fact, it is estimated that elite male marathoners may lose greater than 8% of their body mass due to a major sweat loss to fluid intake deficit (Beis, Wright-Whyte, Fudge, Noakes, & Pitsiladis, 2012). In contrast, it would be almost unthinkable to invite someone to partake in a salty meal or snack without a beverage also being offered. This concept is critical in understanding what Nutrition Coaches can do to optimize fluid intake between exercise (more on this later).

Thirst sensation is also related to the other two major actions that cause a loss of body water. These losses come in the form of sweating or urine production, both hypo-osmotic, which results in decreased blood pressure due to a loss in total blood volume, or hypovolemia. Sensors in the body known as baroreceptors detect these changes and can stimulate thirst drive. Under normal conditions, total-body water losses are minimal and severe thirst is not typically experienced without intake of salty foods. However, physical activity in warm environments can result in sweat rates up to and exceeding 3 liters per hour. These fluid losses do not typically result in a thirst response that matches fluid intake to sweat losses in the first few hours after exercise, which can lead to inadequate recovery fluid consumption.

Several physiological factors have been discovered that help explain this form of short-term *voluntary* (or sometimes referred to as *involuntary*) dehydration. Sweat is hypo-osmotic, and one of the major adaptations of training in a warm environment is a shift to even less salty sweat. In a seminal study, Nose, Mack, Shi, and Nadel (1988b) documented that a primary reason for the sodium-diluted sweat is that water shifts out of the ICF to the vascular ECF space. This movement of fluid from the ICF space keeps total blood volume from decreasing and serves to maintain blood pressure but also limits the increase of plasma osmolality, the major dipsogenic stimulus.

When a considerable volume of water (but less water than was lost in sweat) is consumed after dehydration, much of it remains in the ECF, further decreasing plasma osmolality-related thirst drive (Nose, Mack, Shi, & Nadel, 1988a).

Critical!

Plasma osmolality is a key driver of thirst. If you are working with athletes who need to replace large volumes of sweat lost, consuming meals or snacks with sodium will promote a natural increase in fluid intake and also aid in retention of ingested fluids.

Food for Thought

The main ingredients (water, carbohydrates, and salt) of sport beverages have remained consistent since their inception. However, the concentrations of carbohydrates and electrolytes have been reduced over the years to improve the gastric emptying rate (GER) and increase carbohydrate availability during exercise. The only situation that essentially requires sport-beverage consumption is during intense and prolonged training. Drinking sport beverages during recovery is more of a beverage preference than a necessity, as most Western diets are already rich in carbohydrates and electrolytes (i.e., salt). The caloric impact of a sports beverage should be considered when choosing recovery beverages.

Coach's Corner

Recent attempts to quantify the hydration efficiency of 13 popular beverages have led to the creation of a Beverage Hydration Index. (For more detailed information see Maughan et al., 2016.) Hydration efficiency was calculated as the volume of urine produced over a 4-hour period following ingestion of 1 liter of each beverage type. Milk bested all other common beverage types, including a sports drink, in regard to decreasing volume of urine production after fluid intake. Milk is touted as an excellent recovery beverage for a variety of factors (Pritchett & Pritchett, 2012; Shirreffs, Watson, & Maughan, 2007) and includes protein, fat, and micronutrients not included in sport beverages.

## Effects of dehydration

**Hydration and heat illness**

Regulation of body temperature during exercise is influenced by total-body water levels in multiple ways. However, it is critical to understand that hydration status alone does not determine whether a physically active individual or athlete will experience a heat-related illness or heat stroke.

Many individuals falsely assume that hydration is the key to preventing these incidents. Abstention from overexertion in hot external environmental conditions or microenvironments (e.g., very hot conditions created by working in a hazardous-materials suit despite moderate environmental conditions) is the best defence against experiencing a heat-related illness, but not even exercising or competing in cold weather can prevent all cases of heat illness (Roberts, 2006). Some heat can be dissipated from the body via movement of the blood to the skin if the external environment is cooler than the body’s internal environment (e.g. average body temperature is around 36.6 ºC (98 °F), but most gyms keep the temperature around 21 ºC (70 °F)).

Increased body water can also reduce heat generation related to elevated cardiovascular strain (i.e., higher heart rate while working at the same relative intensity) due to a less efficient venous return associated with decreased total blood volume. The majority of thermoregulation attributed to body water in hot conditions comes from the production and evaporation of sweat. Sweating provides the greatest cooling effect; however, sweating is only beneficial for cooling if it is evaporated from the skin’s surface. The transformation of sweat from a liquid to a vapour produces this cooling effect. An earlier onset of sweating and greater sweat rate are key adaptations that improve tolerance to exercise in hot environments.

### Sweating

Several elements determine sweat evaporation rate. The first is heat. Higher temperatures increase the rate of sweat evaporation. The second factor is humidity. Environments with lower humidity increase the rate of sweat evaporation, often to such a degree that people incorrectly assume they are not actually sweating in hot, arid regions on windy days. Another factor is convection. For nonaquatic activities, convection describes how air movement or lack of air movement increases or decreases sweat evaporation (Infographic: Sweat Evaporation Rate Factors).

Convection can be caused by the wind or by the client’s movement against air, which can be significant in activities like cycling, where athletes routinely propel themselves over 20 miles per hour. When cycling indoors on a trainer or spin bike or running on a treadmill, it becomes easy to notice these indoor sessions seem to result in greater sweat losses than similar efforts outdoors, even if the indoor temperatures are cooler. This misunderstanding occurs primarily due to the fact that the only areas of the body experiencing convection are the legs during spin, or the arms and legs during treadmill running. During outdoor cycling or running, the torso receives considerably more air flow and more sweat is evaporated.

Critical!

Hydration only plays a small role in heat illness or heat stroke. A variety of factors, including environmental conditions, level of exertion, training status, body composition and clothing, may explain individual bouts of heat illness. Euhydration should not be misperceived as all-encompassing protection guarding against heat-related illnesses. Remember, sweating more does not mean more caloric expenditure. Keep tabs on the thermostat and do not programme exercise in the heat for lesser fit, non-heat acclimated clients. Encourage clients to wear breathable clothing and avoid sweat suits.

A poster of a person running and a thermometer

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### How does dehydration influence performance?

Hydration status affects the two major influential factors concerning performance during exercise in a hot environment: cardiovascular and thermo-regulatory functions. In Figure: Hydration Status and Heart Rate, the final heart rates and core temperatures are presented from a study in which 10 men completed a 90-minute, fast-paced walk (3.5 miles/hour (5.6 km/hour) at a treadmill grade of 5% in a hot (33 °C or 91 °F) and humid environment under four hydration conditions.

A screenshot of a blue and white card

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During two trials, participants began exercise euhydrated, and during two other trials, participants began exercise dehydrated. Participants were not permitted to drink at all or were allowed to drink ad libitum under each pre-exercise hydration status. Notice that only one of these conditions resulted in major upward drifts of heart rate and temperature: beginning exercise dehydrated with no access to fluids. Limiting these drifts are major goals when developing hydration strategies. It is critical to note that even when exercise was begun with severe dehydration (loss of water equal to 3% body mass — e.g. 6 pounds (2.7 kg) of water loss for a 200-pound (91 kg) client) followed by exercise inducing an additional litre of sweat loss, simply drinking to natural preferences was enough to offset the upward drifts of heart rate and rectal temperature.

It should be noted that the low relative exercise intensity and continuous opportunity to drink resulted in a nearly six-fold fluid consumption (about 1.7 litre versus 0.3 litre) versus exercise initiated in a euhydrated state. This level of fluid intake is not likely palatable during more intense training and emphasises the importance of between-training-session fluid intake. Half-marathon running studies conducted under similar hot environmental conditions from both the field (Lee, Nio, Lim, Teo & Byrne, 2010) and laboratory settings (Dion, Savoie, Asselin, Gariepy & Goulet, 2013) suggest that most endurance athletes will only replace 15 to 20% of their sweat losses during longer duration training bouts or competitions.

It is also important to note that the low-fluid replacement volumes exhibited in these two studies resulted in many participants experiencing body temperatures greater than 40 °C (104 °F), even though no runners experienced symptomatic heat-related illness.

Critical!

During activities with high thermal stress, Nutrition Coaches should offer free access to a variety of fluid types during preplanned hydration breaks and encourage clients to drink on their own because thirst dictates more fluid intake.

Coach's Corner

Before continuing, look back at your answer to Scenario 1 in the first Try This (Scenario 1 provided below).

Scenario 1: After refraining from working out for several years since high school, a friend tells you that a week of upper-body weightlifting has resulted in repeatedly dark urine colour and very stiff and swollen elbow joints.

Exertional rhabdomyolysis (ER) (often referred to as rhabdo) is a condition in which muscle cell membranes rupture and leak high amounts of proteins, such as myoglobin and creatine kinase, into the extracellular fluid after abnormally hard or new exercise routines. ER is most commonly identified by athletes producing very-dark urine. Unusual puffiness, stiff and swollen joints, and abnormal muscle soreness are also key symptoms of ER. Because the kidneys must handle the excess nitrogen/amino acids loads released from the increased circulating proteins, renal dysfunction is the primary medical concern from ER. Joint swelling is a result of widespread inflammation substrates and fluids shift into the lymphatic system, which accumulate at bends in the body such as the elbows. Clients and athletes with symptoms of ER should be advised to seek medical help immediately and discontinue training until a diagnosis and treatment (usually rest and IV fluid replacement) can be made. Dehydration is often linked as a cause of ER. It is critical to note that this is not the case; rather, the severe muscle damage is the instigator. However, like cardiovascular and thermo-regulatory drift, it is possible chronic dehydration could potentially exacerbate ER-related renal injury. For an excellent in-depth discussion on ER read (Brudvig & Fitzgerald, 2007).

## Developing hydration strategies

Dehydration for clients is often caused by excessive sweating or lack of fluid intake. However, in some cases, dehydration can also be a result of an illness (e.g. vomiting and diarrhoea) (Cheuvront & Kenefick, 2014).

Clinically, dehydration andeuhydration are not defined by total body water but by plasma osmolality or sodium concentrations.

In contrast, for both the scientific and exercise and sport communities, dehydration is often described and expressed as an acute change in total body water, not a change in osmolality.

Euhydration is also commonly defined in the laboratory based on urine solute concentration (e.g. urine-specific gravity). The lack of a single operational definition results in very different interpretations at times. For example, Volpe, Poule and Bland (2009) reported (using urinalysis techniques) that only 34% of 263 collegiate athletes were euhydrated before practice. In contrast, Hew-Butler, Eskin, Bickham, Rusnak and VanderMeulen (2018) found that out of 318 blood samples provided by collegiate athletes, not a single sample would have been classified as dehydrated based on serum sodium norms.

There are multiple reasons why dehydration is used and expressed as a change in total body water in the field versus the plasma osmolality status. Measurement of plasma osmolality or sodium concentration requires a blood draw and expensive analysers to determine a clinical definition of the hydration status. With this in consideration, almost any use of these markers to determine real-time hydration status in a gym or athletic setting is eliminated. In contrast, acute sweat losses can be simply tracked by changes in body mass, and fluid intake is easily measured.

The following section has been prepared with the limitation in mind: that hydration status measured in the clinical sense is not a likely possibility in the exercise realm and that change in total body water does not always correspond uniformly to acute osmolality or sodium concentration levels.

Getting Technical

Total body water shifts are primarily, but not only, related to sweat losses, urine voids and beverage intake. In dry climates, water loss also occurs through evaporative loss of fluids in the mouth and respiratory tract. The aerobic pathway process used to produce energy as adenosine triphosphates (ATP) also result in the formation of new water molecules in the body. Fortunately, under most conditions, these secondary factors are not robust enough to substantially alter the total-body water shift. See Maughan, Shirreffs and Leiper (2007) for a deeper look.

Developing individualized hydration plans for clients is a three-step process. The first two procedures include establishing sweat-loss volume from routine exercise sessions and determining if clients begin training in a euhydrated status. Once this information is established, fluid prescription during and between exercise bouts can be developed, if warranted.

### Sweat-loss assessment

It is possible to drive a car without a functioning fuel gauge, but you will only run into trouble if you fail to fill your petrol tank up frequently enough. This analogy is an almost perfect metaphor for describing the importance of sweat-loss assessment before developing a hydration strategy for a client. Dehydration from sweat loss rarely has severe negative effects on performance or impairs health. Trainers know this because they have survived 100s, if not 1000s, of workouts without incident. Most client's workouts will likely not produce major sweat losses (analogous to a short car trip), and those losses can be easily replaced by ad libitum fluid intake during training and recovery (analogous to frequent stops for petrol).

Sweat-loss assessment allows the Nutrition Coach to determine if their clients do indeed experience major fluid deficits and if any intervention is needed. There are two key differences with regard to hydration using the petrol gauge analogy.

1. A vehicle’s performance will not suffer simply because your gas tank is low, only when it is completely out of gas. In contrast, exercise capacity can potentially be impaired from a significant fluid deficit.
2. Overfilling the gas tank is not that big of a deal unless it spills out of the tank, which can become hazardous. Similar to this hazard, extreme overdrinking can potentially result in death.

Consider the following questions:

1. How do you know how much of a fluid deficit you will incur?
2. How do you determine the level of fluid replacement that will inhibit performance decrement?

Try This

How do you know how much of a fluid deficit your client will incur?

* To determine client sweat rate, you only need a reliable scale, preferably digital for accuracy. Always weigh twice for reliability confirmation.
  + Clients should weigh themselves in the nude in a privacy room. Sweat trapped in clothing will cause an underestimation of sweat losses.
  + Weigh before and after a workout that matches the normal intensity and the environmental conditions of the client. Sweat rates remain very stable if environmental and exercise intensity are consistent.
  + An hour of exercise creates a suitable gauge for estimating sweat losses of shorter- or longer-duration training bouts.
* It is best to avoid using the toilet, if possible, to get the most accurate sweat-loss assessment, and fluid intake must be accounted for (see the interactive sweat-loss calculator).

Helpful Hint

In the United States, body weight is usually measured in pounds and ounces, but beverages are often served in the metric unit of millilitres. If you weigh yourself in kilograms, fluid intake prescription is much easier. A litre of distilled water has a mass of 1 kilogram. Most sport bottles hold around 1 litre (1000 millilitres) of fluid. A half-litre (500 millilitres) of water is the size of a common plastic water bottle and a race aid station paper cup is usually around a quarter of a litre (250 millilitres).

Calculating Sweat Loss

|  |
| --- |
| Initial weight \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ kg  - post-weight in \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ kg  + fluid consumption between weigh-ins \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ kg  - urine volume \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ kg  Sweat-loss volume \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ kg (L) |
| Example Problem  Joe ran for 1 hour at a pace of 8 minutes per mile in 74 °F (23 °C) weather with low humidity. His nude, pre- and post-weights were 70.0 and 68.5 kilograms, respectively. He drank 0.350 kilograms (liters) of water from his bottle. He did not use the restroom during his run.  Initial weight 70.0 kg  - post-weight in 68.5 kg  + fluid consumption between weigh-ins 0.350 kg  - urine volume 0 kg  Sweat-loss volume 1.850 kg (L) |

The American College of Sports Medicine (Sawka et al., 2007) recommends that fluid intake should not exceed sweat-loss volume and a fluid deficit should be limited to less than 2% of body mass. For a 70-kilogram (154-pound) client, this would mean that fluid intake should not allow body mass to decrease by more than 1.4 kilograms (i.e. 2% of body mass) or exceed 70 kilograms during exercise.

While this sounds ideal in theory, research examining runners (O'Neal et al., 2012; O'Neal et al., 2014; Passe, Horn & Murray, 2000; Shaver, O'Neal, Hall & Nepocatych, 2018) and team-sport athletes (Love, Baker, Healey & Black, 2018; Thigpen, Green & O'Neal, 2014) have repeatedly confirmed that athletes experiencing training bouts that cause sweat losses greater than 2% of body mass cannot accurately estimate their sweat losses.

The miscalculation of sweat losses is almost always in the direction of underestimation. There is ongoing debate concerning whether a 2% loss in body mass from dehydration is a valid indicator of performance impairment (Baker, Dougherty, Chow & Kenney, 2007; Dion et al., 2013; Sawka & Noakes, 2007). Regardless, valid fluid intake prescription can only be made if a reasonable estimation of sweat losses can be established.

Coach's Corner

Physically active individuals are not cognisant of the amount of sweat losses they incur. In fact, a survey of close to 300 long-distance runners (when asked to describe how they monitored their hydration status) found less than 3% reported weighing themselves before and after runs to determine their sweat losses (O'Neal et al., 2011). Figure: Actual vs Estimated Sweat Loss compares sweat-loss estimation averages to actual sweat-loss averages for a variety of studies that further demonstrate this point. It is evident from this figure that if athletes are attempting to drink to prevent a certain amount of fluid deficit, they are doing so with a broken petrol gauge.

The figure confirms the general trend of sweat loss underestimation across activity types, but what really matters for the Nutrition Coach is the ability to improve the performance of the individual.

A graph of different colored bars

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Figure: Estimated Sweat Loss vs Actual Sweat Loss provides insight when estimating sweat loss. Each dot represents an individual. The position of each dot is based on the participant’s estimated (*y* axis) and actual (*x* axis) sweat losses following a 1-hour run in the heat. A closer look reveals how much variability (0.75 to nearly 3 litres!) there is in sweat losses among individual runners. For this simple reason, it is highly inappropriate to ever suggest blanket fluid intake guidelines. Knowing the client’s expected sweat losses allows the Nutrition Coach to make informed and correct fluid-intake recommendations.

A graph with blue dots

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Revisit Scenario 2 below. A tri-athlete is rejoicing over a road bike that could hold an immense volume of water bottles. What if the scenarios previously described were reversed and an athlete experiencing low relative sweat losses drank under the impression that their sweat losses were much greater?

Scenario 2:

A triathlete and member of your local endurance sport club has posted a picture of a very-new and expensive road bike. Statements are made that the new bicycle is very light and also has five, 1-litre bottle holders!

Food for Thought

A convincing argument can be made that athletes should only *drink to thirst* (Hoffman, Cotter, Goulet & Laursen, 2016), and multiple hydration guidelines have been written on this premise (Hew-Butler et al., 2005; Hew-Butler et al., 2008; Hew-Butler et al., 2015). However, there are examples of individuals developing Exercise Associated Hyponatremia (EAH) that either do not follow their body’s cues to prevent over-drinking or psychological factors override physiological signals. These incidents are most likely to occur in low-intensity activities of prolonged duration such as hiking, and it possibly impacts females more commonly (Backer, Shopes, Collins & Barkan, 1999; Kenney & Chiu, 2001; O'Neal et al., 2012).

O'Neal, Poulos and Bishop (2012) examined the ad libitum fluid intake of 27 women drinking water and a variety of non-caloric sport beverages with different ingredient combinations during a 1-hour long, hot summer-time walk and 2-hour recovery period. One participant exhibited a profound concern about dehydration and researchers had to provide the participant with a urine container so she could step into the library to pee during every walking session! Table: Hydration Behaviour of an Active Female displays this woman’s data from the study.

Hydration Behavior of an Active Female

| **Comparison of hydration behavior of a physically active female with unfounded excessive concern about hydration – These values are averaged over 5 days of testing with five different beverages.** | **Outlier Participant** | **All Participants** |
| --- | --- | --- |
| Pace (km/hour) | 6.3 | 6.0 |
| Mean heart rate (beats/min) | 128 | 132 |
| Sweat loss (mL) | 590 | 526 |
| Pre-exercise USG | 1.004 | 1.016 |
| Exercise fluid consumption (mL) | 890 | 289 |
| 2-hour recovery consumption (mL) | 390 | 225 |
| Total consumption (mL) | 1280 | 514 |
| 3-hour urine voids (mL) | 1120 | 196 |

The data in this tabel was reformated from O'Neal et al, 2012.

The participant’s pace, heart rate and sweat losses were similar to the rest of the group, but her hydration behaviour was a far outlier. Her average pre-exercise USG was 12 units lower than the other 27 women, suggesting she was hyper-hydrated prior to exercise. However, her fluid consumption exceeded her peers by 250%, and her urine production was an astounding 570% greater than the other walkers as her kidneys were working aggressively to offset the excessive water load in her ECF.

If someone continues to excessively hydrate for extended periods of time during exercise, it is possible for exercise associated hyponatremia (EAH) to occur. Working knowledge of sweat rate and volume can help avoid situations of EAH in most conditions.

Getting Technical

EAH is a potentially deadly medical condition most commonly caused by fluid intake that greatly exceeds sweat loss, which dilutes ECF sodium levels. As a result, an influx of water into the ICF space can lead to cells in the brain stem rupturing, leading to a coma or death. Multiple factors can lead to exacerbated risk of EAH. During exercise, blood flow to the kidneys is greatly diminished, resulting in reduced clearing of the excess fluid. Some individuals over-aggressively hydrate before exercise and others are genetically predisposed to altered hormonal regulation that causes the body to produce less urine than it should. It is important to teach clients to listen to their own body’s cues to not drink in excess of natural thirst.

Coaches are not expected to diagnose EAH but should be aware of the signs and symptoms of EAH. Athletes experiencing EAH with severe symptoms (e.g. seizures or coma) will likely be unable to continue drinking and need to seek medical attention. However, the less-severe symptoms of EAH (such as weakness, cramping, vomiting, disorientation or confusion) may also be experienced during severe dehydration, but should still be treated medically as this is outside the scope of practice for a Nutrition Coach. When assisting someone who is showing signs of hypo- or hyperhydration, always determine the individual’s recent fluid intake. If they report drinking heavily, continued fluid consumption should be restricted. Severe thirst or lack of thirst may help indicate if an athlete is dehydrated or experiencing EAH. If EAH is expected, get the athlete to a hospital as quickly as possible, where sodium levels can be formally evaluated.

Coach's Corner

The good news is that EAH is uncommon and athletes should not have an irrational fear of EAH. There are several competition or training scenarios that are more likely to result in EAH.

* Training or competition sessions that last 4 hours or longer – caution should be given in overzealously promoting fluid consumption.
* High fluid intake during cool environmental conditions that do not result in high sweat rates
* Individuals with lower body mass that take longer to finish an event may exhibit a greater relative fluid intake to body mass ratio.

### Pre-exercise hydration status assessment

The pre-exercise hydration status of the athlete also impacts hydration recommendations. Determining pre-exercise status is complicated and each method of assessment has weaknesses (Armstrong, 2007). Measuring plasma osmolality is obviously impractical in a non-clinical setting, such as a fitness facility. On the opposite end of the spectrum, thirst sensation is easily and freely measured (Davis et al., 2014; Lopez et al., 2011; Stearns et al., 2009; Wilcoxson, Johnson, Pribyslavska, Green & O'Neal, 2017). The most popular remaining options to detect pre-exercise hydration status include changes in body mass and various forms of urinalysis.

**Thirst and body mass as indicators of hydration status**

In regard to changes in body mass to detect hydration status, it has been proposed that athletes record their morning body weight after making voids over a 3-day period and use a 1% decrease from the 3-day body-mass average as a marker of hypohydration (Cheuvront et al., 2004). However, it is unlikely establishing a 3-day baseline for body mass and checking for deviations from that body mass is commonly practised.

It may be logistically difficult to get accurate 3-day body-mass averages of clients already engaged in training. A simple body mass change from training session to training session is more likely used in the field setting, but this method also has flaws. Many training sessions are separated by unequal periods of recovery. Meal consumption and bowel movements may impact pre-exercise body mass. There is no universal guideline for what percentage of body mass should be returned before the next practice begins.

Like thirst, great sweat losses followed by unusually restrictive fluid intake during recovery will produce pronounced differences in body mass (Lopez et al., 2011; Stearns et al., 2009). However, data from studies that have induced significant sweat losses followed by less-restrictive fluid allowances suggest change in body mass may not be well representative of recovery fluid intake. Davis et al. (2014) found that the replacement of 75 versus 150% of sweat losses from a 75-minute run in the heat over a 12-hour period only produced a difference of about 0.5 kg in body mass — due to the effectiveness of the kidneys to retain fluid when intake is less than ideal but not restricted during recovery.

Under a similarly designed protocol, Wilcoxson et al. (2017) required trained runners to lose about 3% of body mass on three separate occasions followed by 1.6, 2.1, or 2.6 litres (approximately 70, 100 and 120% replacement of sweat loss) of multiple beverage types over a 12-hour recovery period. Fluid replacement at these three levels resulted in approximately 0.5, 0.9 and 1.4 litres of urine production. Because of the vast differences in urine production, the average difference in change in total body water was less than 0.2 litres!

Both of these studies controlled all food intake over the 12-hour recovery testing period and still found no clear change in body mass that differentiated between different recovery fluid replacement levels. In summary, thirst sensation and change in body mass are likely great indicators of pre-exercise hydration status if fluid intake after the previous exercise bout is highly insufficient, but diagnostic legitimacy may decrease under more ecologically valid conditions.

**Urinalysis as an indicator of hydration status**

Urine osmolality, colour and specific gravity are also used to gauge the real-time hydration status. The impracticality of using osmolality, even from urine versus blood, has already been discussed. The highly popular urine colour scale (Armstrong, 2000) was developed as an alternative to techniques that required laboratory instruments and is often found in fitness facility locker rooms. Urine colour, like thirst or the change in body mass, is excellent at distinguishing between extremes of recovery fluid intake but is not particularly sensitive to less contrasting levels of recovery fluid intake that would likely be experienced by clients (Wilcoxson et al., 2017). This may be due to the subtle differences in shading for the identifying markers in the middle of the eight-level urine color chart (Figure: Urine Chart).

A chart with numbers and text

AI-generated content may be incorrect.

Thought must also be given to how the urine colour is measured. The chart was designed to be used after urine is collected in a clear container, but most athletes likely examine their urine after it has been diluted in toilet water.

Urine-specific gravity may be an option for Nutrition Coaches looking for a more objective way to determine if clients are adequately rehydrating between training [Figure: Urine-Specific Gravity (USG)].

A diagram of a measuring device

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Getting Technical

Urine-specific gravity (USG) is a scale that represents the ratio by which the pathway of light is bent (or refracted) after travelling through a liquid in comparison to light passing through water that has no solute content. The picture above is a picture of a manual refractometer (purchased for <$150), which can assess USG.

A drop of urine is placed on the lens of the refractometer and a metered scale in the viewfinder is used to determine the refraction ratio.

As the kidneys attempt to conserve body water, more solutes and less water will be found in the urine. Hyperhydration results in the kidneys trying to clear excess water and the urine will be more dilute. Assessing USG is simple. Nutrition Coaches may consider adding this assessment to better serve their clients needing hydration advice.

Figure: Relationship Between Percentage of Sweat Loss Replaced and USG below presents the USG 12 hours after 60 to 90 minutes of running and the percent of sweat losses replaced during recovery.

A graph of a graph with blue and green dots

AI-generated content may be incorrect.

There is a strong but imperfect relationship between the fluid replacement percentage and USG, and the relationship’s strength is improved in runners that lose greater relative percentages of sweat (purple triangles). When runners lost greater than 3% of their body mass, USG correctly identified the recovery fluid intake adequacy just shy of 85% of the time. Correct identification fell to less than 70% for those individuals who sweated less.

Again, under this scenario, USG is not meant to be a substitute for a clinical hydration classification (i.e. plasma osmolality). Instead, frame it as a tool to identify clients that experience heavy sweat losses and repeatedly show up to train without adequately replacing fluids between training sessions.

Coach's Corner

Tips to Hydration Education and Recommendations

Traditionally, a USG exceeding 1.020 has been used as a dichotomous hydrated/dehydrated measure. USG may be more useful as an indicator of adequate recovery fluid consumption.

Measure USG prior to multiple training sessions to gain a global picture of the individual client’s chronic hydration behaviour. USG meeting or exceeding 1.030 likely indicates a significant failure to replace fluids, while a reading closer to 1.020 probably indicates a less-significant lack of adequate fluid replacement.

Help athletes that repeatedly exhibit USG of 1.025 or greater to assess their sweat rates in training (see the sweat-loss calculator) and prepare a plan to intentionally replace about 110 to 120% of their expected sweat losses from practice with fluids from a metered bottle.

**Fluid intake during and between training**

Before a Nutrition Coach provides any hydration recommendations to their clients, they must ask themselves if there is a genuine need for fluid intake advice. Dehydration is an easy culprit to blame when a training session or competition does not go as planned, but Nutrition Coaches should only intercede when intervention is actually needed (i.e. when sweat losses from training are great and clients fail to adequately hydrate between training bouts).

There is disagreement on the precise percent of body mass lost through sweating that leads to impaired performance (Dion, Savoie, Asselin, Gariepy & Goulet, 2013; Sawka & Noakes, 2007). Anecdotally, less-well-trained and non-heat acclimatised individuals are more likely to suffer impaired performance associated with dehydration than their more elite peers. A simple recommendation is that if fluids are freely accessible during training and sweat losses will be less than about 3% of body mass, no formal hydration advice concerning beverage consumption is needed during exercise. This covers the vast majority of training or competition circumstances.

Some clients will actively seek hydration advice. If sweat loss and pre-exercise hydration evaluations suggest no intervention is needed and this appraisal is too anti-climactic for your clients, simply encourage consumption of 500 mL of water before bed and another 500 mL of water in the 2 hours before exercise.

**Fluid intake during exercise**

For Nutrition Coaches who work with athletes, the main difference for endurance and team-sport-based athletes is that most team-sport practices and games typically have built-in periods of rest where fluid consumption can take place without difficulty. For Nutrition Coaches who work with team-sport athletes who do experience great sweat losses, it is critical that ample breaks and a variety of beverages to encourage fluid consumption are provided. Keep in mind that when provided with the opportunity to drink, most, but not all individuals will consume fluids to prevent the cardiovascular and thermo-regulatory impairment caused by dehydration (Armstrong & Maresh, 1998).

For endurance athletes, there are many options to preplan drinking opportunities: place fluids along routes, plan routes that pass convenience stores or water fountains, carrying hydration packs on their backs or bikes, place drinks on pool decks, use hand bottles, etc. Ideally, a sweat-loss assessment analysis should be incorporated before competition to determine the minimal amount of fluid that must be consumed to prevent excessive dehydration. The athlete should also practise their competitive fluid-intake routine strategy during training to determine if the fluid consumption volume or beverage type will result in gastrointestinal distress. All of these factors can also be incorporated when working with non-athlete clients to encourage day-to-day euhydration.

**Fluid intake during recovery**

Some hydration guidelines prescribe fluid intake for *before* and *after* exercise. A more global terminology of recovery hydration is preferred. The key to recovery hydration is to replace sweat-loss fluids and maximise the retention of those fluids before the next training session. ACSM guidelines (Sawka et al., 2007) suggest that when the recovery period is less than 12 hours, athletes should replace 150% of their sweat losses via beverage fluids.

The idea behind this replacement prescription is that roughly 1/3 of beverage intake will be lost through urine voids. This is entirely appropriate if sweat losses are not great. However, when sweat losses exceed 3% body mass, this volume of fluid replacement is likely unpalatable for many individuals and may produce urine volume greater than 1/3 of the beverage intake, nullifying the additional fluid consumption for many individuals (Davis et al., 2014; Wilcoxson et al., 2017).

Under the scenario that greater than 3% body-mass loss will be incurred and the recovery period will be <12 hours, it is suggested that athletes should aim for replacing at least 110 to 120% of their sweat losses with fluid intake from beverages and acquire additional fluid intake from food sources (Infographic: Fluid Prescription During Training and Recovery).

Sodium, protein and carbohydrate intake support fluid retention by decreasing the relative urine production. It is a popular belief that hunger is disguised thirst. There may be some truth that drinking before eating decreases food intake, but there is no doubt that food consumption encourages fluid consumption. Sodium-rich food items, such as mustard packets, pickle juice or pretzels, increase fluid intake and retention during recovery and are probably only truly needed during very-intense and prolonged training phases.

A diagram of a body mass

AI-generated content may be incorrect.

Eating meals and snacking between training is paramount to optimising recovery hydration efforts. Use the following tips to share with clients:

* Some fruits and vegetables contain up to 90% of their mass as water and also contain potassium, the key ICF electrolyte. Soups are also high in water content and generally contain ample amounts of sodium.
* Many athletes falsely assume water is the only beverage that improves hydration status. All beverages, excluding those with alcohol percentage >4% (McDermott et al., 2017), increase total body water.
* Caffeine has also been miscast as a diuretic for physically active populations, but habitual consumption of caffeine and exercise negate the diuretic effect of caffeine to benign levels (Zhang et al., 2015).

The high sodium content of pickle juice reduces urine output. This strategy might be helpful during very-intense periods of training in the heat, but it is not likely needed if salty food is consumed at meals during recovery.