By Natalie Digate Muth, MPH, RD

CEC APPROVED

HYPONATREMIA: THE OTHER SIDE OF THE HYDRATION STORY

Should you drink as much as you can tolerate when exercising? Or is this time-honored advice all wet?

HYPERCONSCIOUS OF THE DETRIMENTAL health and performance effects of dehydration, health and fitness experts have long warned recreational exercise enthusiasts and athletes alike to hydrate continuously. In fact a 1996 American College of Sports Medicine Position Stand encourages exercisers to drink "the maximal amount that can be tolerated" to avoid dehydration (Convertino et al.1996).

But the latest research reveals that hyponatremia—severely reduced blood sodium concentration resulting from overhydration—may be of equal or greater concern.

Newspaper reports warn of the potential deadliness of an extreme imbalance in either direction. Headlines share the unlikely but real tragedy of the 28-year-old novice Boston Marathon runner who suffered severe hyponatremia and later died en route to the hospital (Smith 2002), as well as the story of the 24-year-old elite marathon runner who collapsed from dehydration while exploring desolate trails in the Grand Canyon's summer heat without sufficient water (Dardick 2004). How do you allay the fears of clients who have read these accounts? You need to familiarize yourself with the physiology, causes and consequences of hyponatremia and dehydration and provide practical tips to help your clients maintain a healthy hydration status during prolonged exercise.

The Physiology of Exercise and Hydration Status

Water constitutes about 60% of an individual's body weight (Von Duvillard et al. 2004); to put this in perspective, approximately 102 pounds (lb) of a 170 lb man is water weight. Physiologically, water has many important functions, including regulating body temperature, protecting vital organs, promoting nutrient absorption and maintaining a high blood volume for optimal athletic performance.

Water volume can be influenced by a variety of factors, such as food and drink intake; sweating; urine and feces excretion; metabolic production of small amounts of water; and losses of water that occur with respiration. These factors play an especially important role when metabolism is increased during exercise. The generated body heat is released through sweat, a solution of water and sodium and other electrolytes (Von Duvillard et al. 2004). If fluid intake is not increased to replenish the fluid lost, the body attempts to compensate by retaining more water and excreting more concentrated urine; when this happens, the person is said to be dehydrated. Severe dehydration can lead to heat stroke, or extreme overheating, which can be fatal if not treated immediately. On the other hand, a person who ingests excessive amounts of fluid to compensate for minimal amounts of water lost in sweat may become fluid overloaded, or hyponatremic. When the blood's water-to-sodium ratio is severely elevated, excess water can leak into brain tissue, leading to encephalopathy, or brain swelling.

The Not-So-Delicate Balance

It seems a lot like the proverbial double-edged sword: Drinking too little can lead to dehydration—a scary condition that exercisers have been cautioned against in every text, handout and presentation on fluid replacement. But drinking too much—out of fear of not drinking enough—could lead to hyponatremia, a condition less well known and understood but equally frightening.

Here's the good news: The body is very good at handling and normalizing large variations in fluid intake. For this reason, severe hyponatremia and dehydration are rare and generally affect very specific high-risk populations during specific types of activities. And both conditions are highly preventable.

Hyponatremia

Hyponatremia is defined as an abnormally low concentration of blood sodium—less than 135 millimoles per liter (mmol/L). Exertional hyponatremia results from excessive intake of low-sodium fluids during prolonged endurance activities (Casa 2003)—that is, drinking a greater volume of fluid than the volume lost in sweat—and possibly, to a lesser extent, from inappropriate fluid retention (Almond et al. 2005).

EXERTIONAL HYPONATREMIA RESULTS FROM EXCESSIVE INTAKE OF LOW-SODIUM FLUIDS DURING PROLONGED ENDURANCE ACTIVITIES (CASA 2003).

"If you are constantly drinking water during exercise but not exercising at an intensity great enough to elicit increased sweat rates, then you may be running the risk of 'diluting' your electrolytes (sodium primarily)," says Jason Siegler, PhD, ATC, a professor of exercise physiology at Brooklyn College. "If you look at who is generally at a greater risk of hyponatremia, it is the 4- to 5-hour marathoner."

In fact a study of 488 Boston Marathon runners published in *The New England Journal of Medicine* found that 13% (22% of women and 8% of men) had hyponatremia, and 0.6% had critical hyponatremia, at the end of the race (Almond et al. 2005). Runners with hyponatremia were more likely to be of low body mass index, consume fluids at every mile (and more than 3 liters total throughout the race), finish the race in more than 4 hours, and gain weight during the run. The greatest predictor of hyponatremia was weight gain, which researchers attributed to excessive fluid intake (Almond et al. 2005).

But hyponatremia is not limited to runners. Anyone exercising at a low to moderate intensity for an extended period of time (generally 4 hours or more) while consuming too much water can be at risk.

"It's a time thing. It could happen to any athlete who is exercising for a long period," says Tara Gidus, MS, RD, American Dietetic Association spokesperson and marathon runner. "But we don't need to worry about it as much in more intense athletes." People exercising at a higher intensity do not generally have the time to drink too much water, Gidus says.

In fact high-intensity exercisers are more susceptible to the other vice—**dehydration.**

Dehydration

Mild dehydration, or a 1%–2% loss of body weight during exercise, is normal and of no great concern, according to a USA Track & Field (USATF) advisory (Casa 2003). In fact most competitive marathoners are mildly dehydrated at the end of the race. However, the advisory warns, greater losses should be "avoided if at all possible," since more severe dehydration is clearly associated with alterations in cardiovascular function, thermoregulatory capacity and muscle function, as well as heat illness (Casa 2003).

Dehydration results from a sweat rate that is beyond fluid replenishment. Several factors increase the likelihood of dehydration, by either increasing sweat rate or decreasing fluid intake.

Increased Sweat Rate. Though larger people generally tend to sweat more than smaller people, all individuals vary greatly in their sweat rates, and fluid replacement should be tailored to individual needs. The following factors could increase sweat rate to the point of dehydration:

- Exercising at very high intensities. Sweat rate is increased; the time available to focus on rehydration is diminished; and the stomach and intestines are less able to process and empty fluids into the bloodstream.
- Exercising in very hot and/or humid conditions. Sweat rate is dramatically increased in an effort to rid the body of excessive heat. Because water also functions to cool the body temperature, severe dehydration in these conditions can lead to heat stroke.

Decreased Fluid Intake. Lack of fluid consumption during exercise can also lead to dehydration. Poor consumption may be due to

- inaccessibility of fluids;
- a low level of fluid tolerance;
- dislike of the available beverage;
- failure to understand the importance of staying hydrated.

A person who is mildly dehydrated at the onset of a workout will be at increased risk of suffering from serious dehydration during the exercise session. This is especially common in athletes who work out several times a day.

Dehydration, high exercise intensity, hot and humid environmental conditions, poor fitness level, incomplete heat acclimatization, and a variety of other factors can all raise body temperature and together can lead to heat stroke. However, according to an article in the *Clinical Journal of Sport Medicine,* heat stroke is exceedingly rare and is often confused with a more common condition, **postural hypotension,** the pooling of blood in the legs and inadequate blood supply to the upper body, causing dizziness, weakness and collapsing (Noakes 2003a). Postural hypotension can be easily remedied by elevating the legs above the head for 3–4 minutes (Casa 2003); nonetheless, **a physician should be immediately consulted to properly diagnose and treat the ailing athlete.**

Symptoms and Treatment of Hyponatremia and Dehydration

The symptoms of hyponatremia and dehydration are, unfortunately, very similar. Symptoms of hyponatremia include nausea, vomiting, extreme fatigue, respiratory distress, dizziness, confusion, disorientation, coma and seizures. Symptoms of dehydration include nausea, vomiting, dizziness, disorientation, weakness, irritability, headache, cramps, chills and decreased performance (Casa 2003). Because the signs of the fluid imbalances are so similar, and dehydration is better understood than hyponatremia, people suffering from hyponatremia may think that they are dehydrated and consume more fluids, thus exacerbating an already severe condition.

So how can you tell the difference? A simple guideline when assessing whether someone is dehydrated or hyponatremic is to look at the individual's risk profile. Is the person a recreational athlete who has been exercising for an extended period of time at a low to moderate intensity with a low sweat rate and a high consumption of fluids? If so, that individual is more likely to be

A PROTOCOL TO DETERMINE INDIVIDUAL FLUID NEEDS

The Goal: Determine sweat rate.

The Calculation: sweat rate = body weight before activity – body weight after activity + fluid intake – urine volume/ exercise time

The Protocol:

- Warm up until you break a light sweat.
- Urinate if necessary.
- Weigh yourself naked on an accurate scale.
- Exercise for 1 hour at an intensity and in environmental conditions similar to those for your normal activity, a target race or other event, depending on your reason for determining your sweat rate.
- Drink a measured amount of fluid, ideally the same type of beverage that you consume normally or will consume during the target race or other event. Convert ounces into pounds (16 ounces = 1 pound).
- Do not urinate during the exercise session unless you plan to measure the volume of the urine. (If you do so, convert ounces into pounds.)
- Weigh yourself naked on an accurate scale.
- Calculate sweat rate (weight before exercise – weight after exercise + amount of fluid consumed – amount of fluid urinated, if applicable/1 hour). Multiply by 16 to determine the number of ounces of fluid needed per hour of exercise.

Protocol adapted from Casa 2003.

10 Ways to Help Clients Prevent Hyponatremia and Dehydration

1. Host a hydration testing clinic at your facility. (See "A Protocol to Determine Individual Fluid Needs" on the previous page.)
2. Use a bulletin board or the club newsletter to keep clients informed of the most up-to-date hydration recommendations.
3. Provide a handout outlining the USA Track & Field hydration guidelines (Casa 2003) or other hydration resources; or include a link to these resources on your facility's website.
4. Focus on hydration recommendations during a staff in-service.
5. Ensure access to cold water, sports drinks and salt tablets for members to use when needed.
6. Provide a scale so clients can assess their fluid status during intensive outdoor sports clinics and other high-intensity or prolonged endurance activities.
7. Encourage clients to pay attention to their thirst and sweating rates and rehydrate appropriately during personal training sessions.
8. Make an effort to announce the latest hydration recommendations during fitness classes, and be available to answer questions afterward.
9. Prevent fluid imbalances during your own training workouts.
10. Volunteer at a local marathon or triathlon, and remind participants of proper hydration guidelines. Advise them to consume no more than 800 milliliters (about 3 cups) of fluid per hour to avoid overhydration.

suffering from hyponatremia. Or is the person soaking in sweat from exercising at a high intensity for an extended period in excruciating heat and humidity with very little access to fluids, in which case dehydration is the more likely problem? While not every case will be this clear, gathering as many clues as possible will help in selecting the most appropriate treatment.

Hyponatremia should be treated by a physician, who can monitor the athlete and provide sodium replacement and a diuretic to rid the body of excess fluid if necessary. Dehydration should also be treated by a physician, especially when symptoms such as vomiting, dizziness and disorientation are present. The physician will treat the athlete with either oral or intravenous fluids, depending on the severity of the dehydration. (Athletes who are conscious, cognizant, without gastrointestinal upset and not at risk of hyponatremia can be encouraged to orally rehydrate themselves.)

Prevention of Fluid Disturbances

Both hyponatremia and dehydration are highly preventable. To help facility members and clients avoid either extreme, it's important to (1) stay up-to-date with the latest research and guidelines and (2) provide clients with that information. Since many of the main fitness organizations have not yet officially updated their fluid recommendations and still encourage exercisers to drink as much as possible, it is wise to base hydration recommendations on the 2003 USATF guidelines (Casa 2003). Exercisers who are highly aware of the risks of dehydration and largely oblivious to the risks of hyponatremia—especially those who participate in long training sessions—should be informed that overconsumption of fluids can be as detrimental as underconsumption.

The following list of recommendations is based on the latest research (see References), the 2003 USATF report and expert advice.

Use Thirst to Determine Fluid Needs. "Runners have been instilled with the concept that hydration must be ahead of thirst and that the presence of thirst indicates dehydration," writes Douglas Casa in the USATF advisory for proper hydration. "However, staying ahead of thirst can lead to overhydration, as thirst is no longer available as a natural signal to know individual fluid needs" (Casa 2003). This recommendation extends beyond runners. Advise clients to drink when they are thirsty and stop drinking when they feel hydrated.

Aim for a 1:1 Fluid-Replacement-to-Fluid-Loss Ratio. Ideally, people should consume the same amount of fluid as they lose. This amount can be determined by using the USATF Self-Testing Program for Optimal Hydration (see "10 Ways to Prevent Hyponatremia and Dehydration," above). Or exercisers can compare body weight before and after exercise. Perfect hydration is when no weight is lost or gained during exercise.

Because people sweat at varying rates, the typical recommendation to consume 3–6 ounces (oz) of water for every 20 minutes of exercise may not be appropriate for everyone. However, when individual assessment is not possible, this recommendation works for most people. Experts advise slightly less for slower, smaller athletes in mild environmental conditions and

THE ROLE OF SPORTS DRINKS

Sports drinks play a key role in replenishing fluids, glucose and sodium lost during exercise lasting more than 1 hour. Although sports drinks may not completely protect against hyponatremia, they serve an important purpose in endurance exercise. This table provides nutrition information for some of the most popular sports drinks.

Drink	Serving Size (oz)	Calories (kcal)	Sodium (mg)	Carbohydrate (g)	Carbohydrate Concentration (%)
Gatorade®	8	50	110	14	6
Gatorade Endurance Formula	8	50	200	14	6
Powerade®	8	70	55	19	8
PowerBar® Endurance	8	70	160	17	7
Propel® Fitness Water	8	10	35	3	1
Ultima Replenisher™	8	12.5	37	3	1

Source: Sports drink websites and product labels.

slightly more for competitive athletes at higher intensities in warmer environments (Noakes 2003b).

Measure Fluid Intake. "Actually measure it out," suggests Gidus. "What does 4, 6 or 8 oz look like?" When exercisers know how much they are actually drinking, they may be able to better assess if they are consuming appropriate amounts.

Drink Fluids With Sodium During Prolonged Exercise Sessions. If an exercise session lasts longer than 2 hours or an exerciser is participating in an event that stimulates heavy sodium loss (defined as more than 3–4 grams [g] of sodium), experts recommend consuming a sports drink that contains elevated levels of sodium (Coyle 2004). Researchers did not find a benefit from sports drinks containing only the 18 mmol/L (or 100 milligrams per 8 oz) of sodium typical of most sports drinks and thus concluded that higher levels would be needed to prevent hyponatremia during prolonged exercise (Almond et al. 2005). (See "The Role of Sports Drinks" above for the sodium content of some popular drinks.) Alternatively, exercisers can consume extra sodium with meals and snacks prior to a lengthy exercise session or a day of extensive physical activity (Casa 2003).

Drink Carbohydrate-Containing Sports Drinks to Reduce Fatigue. "If you are exercising for longer than 1 hour, you should also [get] some additional carbohydrate with your drink," says Seigler. With prolonged exercise, muscle glycogen stores become depleted and blood glucose becomes a primary fuel source, he says. To maintain performance levels and prevent fatigue, experts suggest consuming drinks and snacks that provide about 30–60 g of rapidly absorbable carbohydrate for every hour of training (Coyle 2004). And as long as the carbohydrate concentration is less than about 6%–8%, it will have little effect on gastric emptying (Coombes & Hamilton 2000). (See "The Role of Sports Drinks" for the carbohydrate content of popular sports drinks.)

Hydrate Appropriately Before and After the Event. To maximize pre-event hydration, USATF recommends consuming 17–20 oz of water or a sports drink 2–3 hours before exercise, and 10–12 oz of water or a sports drink within 10 minutes of beginning exercise.

Following exercise, the athlete should aim to correct any fluid imbalances that occurred during the exercise session. This includes consuming water to restore hydration, carbohydrates to replenish glycogen stores, and electrolytes to speed rehydration (Casa 2003). Those at greatest risk of hyponatremia should be careful not to consume too much water following exercise and instead should focus on replenishing sodium.

Pay Attention to Environmental Conditions. Athletes who are well acclimatized to heat will have decreased sodium losses in sweat, reducing the risk of hyponatremia (Casa 2003). Risk of heat stroke rises in conditions of elevated temperature, high humidity and still wind because these conditions diminish the body's ability to dissipate heat into the environment (Noakes 2003b).

The Finishing Line

The human body is well equipped to withstand dramatic variations in fluid intake during exercise and at rest with little or no detrimental health effects. For this reason, most recreational exercisers will never suffer from serious hyponatremia or dehydration and should not be alarmed. It is under extreme situations of prolonged or very high intensity exercise in excessive heat and humidity that risk increases. Even then, if athletes replenish sweat loss with equal amounts of fluid, hydration problems can be avoided. The key to a safe finish is a few ounces of education and prevention.

Natalie Digate Muth, MPH, RD, CSCS, is an ACE master trainer, a dietitian, and a medical student at the University of North Carolina at Chapel Hill. She can be reached at Natalie_Muth@med.unc.edu.

References

Almond, C.S.D., et al. 2005. Hyponatremia among runners in the Boston Marathon. *New England Journal of Medicine, 352* (15), 1550–56.

Casa, D.J. 2003. Proper hydration for distance running—Identifying individual fluid needs: A USA Track & Field advisory. www.usatf.org/groups/Coaches/library/hydration/ProperHydrationForDistanceRunning.pdf; retrieved May 30, 2005.
Convertino, V.A., et al. 1996. American College of Sports Medicine position stand: Exercise and fluid replacement. *Medicine & Science in Sports & Exercise, 28* (1), i–vii.
Coombes, J.S., & Hamilton, K.L. 2000. The effectiveness of commercially available sports drinks. *Sports Medicine, 29* (3), 181–209.
Coyle, E.F. 2004. Fluid and fuel intake during exercise. *Journal of Sports Sciences, 22* (1), 39–55.
Dardick, H. 2004. Runner died of dehydration in canyon, autopsy shows. www.rhaina.com/ChicagoTribune.htm; retrieved May 30, 2005.
Noakes, T. 2003a. Fluid replacement during marathon running. *Clinical Journal of Sport Medicine, 13,* 309–18.
Noakes, T. 2003b. Overconsumption of fluids by athletes. *British Medical Journal, 327,* 113–14.
Smith, S. 2002. Marathon runner's death linked to excessive fluid intake. *Boston Globe* (August 13). www.remembercynthia.com/hyponatremia_bostonglobe.htm; retrieved May 30, 2005.
Von Duvillard, S.P., et al. 2004. Fluids and hydration in prolonged endurance performance. *Nutrition, 20,* 651–56.

"IF YOU LOOK AT WHO IS GENERALLY AT A GREATER RISK OF HYPONATREMIA, IT IS THE 4- TO 5-HOUR MARATHONER."
—JASON SIEGLER, PHD, ATC

RESOURCES

Gatorade Fluid Loss Calculator (www.gatorade.com/3_science/fluid_loss/fluidcalc/fluidcalc_calculator.htm). Input the exercise type, intensity and duration; the environmental temperature; and your body weight to estimate your individual fluid needs.

PowerBar Hydration Calculator (www.powerbar.com). Use this convenient calculator during a 1-hour test workout to determine the amount of sports drink required to keep your body properly hydrated while exercising.

USA Track & Field (www.usatf.org). Access an electronic library of information on hydration and a handout outlining the protocol for determining individual fluid needs.