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National Athletic Trainers' Association Position Statement: Fluid Replacement for the Physically Active

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Objective: To present evidence-based recommendations that promote optimized fluid-maintenance practices for physically active individuals.

Background: Both a lack of adequate fluid replacement (hypohydration) and excessive intake (hyperhydration) can compromise athletic performance and increase health risks. Athletes need access to water to prevent hypohydration during physical activity but must be aware of the risks of overdrinking and hyponatremia. Drinking behavior can be modified by education, accessibility, experience, and palatability. This statement updates practical recommendations regarding fluid-replacement strategies for physically active individuals.

Recommendations: Educate physically active people regarding the benefits of fluid replacement to promote performance and safety and the potential risks of both hypohydration and hyperhydration on health and physical performance. Quantify sweat rates for physically active individuals during exercise in various environments. Work with individuals to develop fluid-replacement practices that promote sufficient but not excessive hydration before, during, and after physical activity.

Key Words: athletic performance, dehydration, hydration protocol, hydration status, hyponatremia, oral rehydration solution, rehydration, overhydration, fluid overload

In humans, total body water and overall hydration are normally maintained within a relatively narrow range (1% hyperhydration to 3% hypohydration).[1,2] The benefits of optimal hydration status include maintaining athletic performance,[3–6] maximizing the transfer of metabolic heat,[5,7] maintaining mood,[8,9] and facilitating recovery from exercise.[10,11] All may be compromised at modest levels of hypohydration (approximately 2%).[5,9] However, extreme deviations on either end of the physiological range (hypohydration or hyperhydration) can compromise health and organ function.[12–14]

A majority (more than 50%) of athletes in professional sports,[15] collegiate athletics,[16,17] and high school[18] and youth sports[19,20] arrive at workouts hypohydrated. When access to fluids based on thirst and voluntary fluid intake is adequate during activity, humans replace roughly two-thirds of sweat losses.[21–25]

Maintaining hydration status with minimal variation (+1% to –1%) allows the body to optimally thermoregulate[5,26,27] and maintain cardiovascular function.[7,28,29] Evaporative heat loss is the most effective mode of heat dissipation in warm or hot conditions. If the eccrine sweating mechanism is compromised due to a lack of available body fluid, core temperature increases above that expected for the activity and environment.[30,31] Appropriate hydration is similarly important for physical activity at altitude, for individuals with chronic disease, and for thermoregulation in cold environments.[32,33]

Conversely, excessive fluid consumption can lead to life-threatening exercise-associated hyponatremia (EAH), in which extracellular body water enters the cells and causes organ and tissue swelling.[34,35] Although EAH is uncommon in team-sport athletes, it has been identified in 10% to 20% of distance athletes after events.[35–38] The condition can be fatal when brain cells swell and brain tissue herniates through the foramen magnum or the brain swelling triggers noncardiogenic pulmonary edema that leads to respiratory failure.[34] It is imperative that individuals remain within or close to the normal range of plasma volume and serum osmolality to prevent substantially low or high body water volumes before, during, and after physical activity and to maintain performance and health.

This position paper is an update to the previous National Athletic Trainers' Association (NATA) position statement on fluid replacement for athletes (published in 2000). It expands the scope of recommendations and updates the topic of fluid replacement based on recent literature regarding hydration in physically active individuals.

PURPOSES

This position statement is based on an extensive literature review and includes definitions of normal and abnormal hydration and fluid-balance recommendations to help athletic trainers (ATs) and other health care providers

1. Understand that fluid losses and needs are variable and that fluid-balance needs must be individualized for best results.
2. Educate physically active individuals on how to maintain their hydration status in order to avoid moderate to severe hypohydration and EAH and promote safety and performance.
3. Know the importance of approximating or maintaining euhydration before, during, and after exercise in physically active individuals.
4. Develop hydration strategies to follow before, during, and after physical activity.
5. Recognize the signs and symptoms of hypohydration and EAH to enable differentiation of hydration concerns from exertional heat illness and also understand diagnostic procedures and point-of-care blood analysis.
6. Acknowledge when on-site treatment is appropriate for hypohydrated or hyponatremic patients and when to transfer for evaluation and management at an advanced medical facility.
7. Identify unique personal characteristics (eg, age, disease states) and environmental variances (eg, altitude, cold) that may alter the regulation of fluid balance during exercise.

DEFINITIONS

Euhydration

Euhydration is the state of optimal total body water content as regulated by the brain. Intracellular and extracellular fluid volumes are maintained with minimal physiological adjustment. The body's systems function most efficiently in this state.

Hyperhydration

Hyperhydration is the state of excessive total body water content with expanded intracellular and extracellular fluid volumes. The body normally excretes the excess fluids.

Exercise-Associated Hyponatremia

A potentially fatal condition, *EAH* is defined as a serum sodium concentration of less than 135 $\text{mmol}\cdot\text{L}^{-1}$ during or within 24 hours of physical activity.[13,34–36] Exercise-associated hyponatremia is a potential medical emergency that is typically symptomatic at levels below 130 $\text{mmol}\cdot\text{L}^{-1}$.

Dehydration

The process of losing body water is known as *dehydration*. During exercise, body water is most often lost through sweating. Water loss through urine (eg, diuretic use), respiration, feces (especially with diarrhea), or vomiting can also dehydrate the body.

Hypohydration

Hypohydration is a deficit of body water that is caused by acute or chronic dehydration. Hypohydration represents a continuum from both a clinical perspective (mild = 1% to 5%, moderate = 5% to 10%, and severe = >10% body mass deficit) and an athletic perspective (mild to moderate = 2% to 5% and severe = >5% body mass deficit) where mass = volume. In athletes, a deficit greater than 5% is consistently associated with impaired performance, extreme thirst, headache, and other symptoms; such a fluid deficit is difficult to replace, even with extended recovery time.

Drinking ad libitum

Derived from the Latin, *drinking ad libitum (ad lib)* means "drinking at one's pleasure." This consists of consuming fluids when desired and of the selected or preferred concentration, flavor, consistency, temperature, etc. However, this strategy does not necessarily include the ongoing assessment of thirst.[21]

Drinking to Thirst

Consuming fluids as thirst dictates is called *drinking to thirst*. Thirst is the psychological sensation of and motivation for seeking fluids to consume. This strategy involves consuming fluids when thirsty and drinking enough to limit the sensation of thirst before and throughout activity.

EVIDENCE CLASSIFICATION

Strength of Recommendation Taxonomy

The recommendations in this statement are supported using the Strength of Recommendation Taxonomy (SORT) system.[37] The letter indicates the consistency and evidence-based strength of the recommendation (*A* reflects the strongest evidence base). For the practicing clinician, any recommendation with an A grade warrants attention and should be inherent to clinical practice. Less research supports recommendations with grades B and C; these should be discussed by the sports medicine staff. Grade B

Table 1. Signs and Symptoms of Hypohydration and Hyponatremia

Hypohydration (Decreased Total Body Water)	Hyponatremia (Low Blood Sodium Concentration)
Thirst	Altered mental status
Flushed skin	Muscular twitching or weakness
Apathy[a]	Apathy[a]
Dizziness or lightheadedness[a]	Dizziness or lightheadedness[a]
Nausea, diarrhea, or vomiting[a]	Nausea or vomiting[a]
Heat sensations or chills	Acting "out of sorts"
Headache[a]	Headache (progressive and severe)[a]
Dyspnea (only in severe cases)[a]	Dyspnea[a]
Gastrointestinal cramping	Swelling of hands, feet, or both
General discomfort	Mood changes
Acute body weight loss	Disorientation or confusion
	Grand mal seizure or coma
	Acute weight gain

[a] Signs or symptoms that are common in both conditions, necessitating blood-sodium assessment for differentiation before treatment. Note: A patient can be hypohydrated and hyponatremic at the same time.[35,36,38,50]

recommendations are based on inconsistent or limited controlled research outcomes. Grade C recommendations should be considered as expert guidance despite limited research support.[37]

RECOMMENDATIONS

Importance of Maintaining Fluid Balance and Regulation

1. Among individuals in free-living conditions, habitual fluid intake and urine production are highly variable.[1,20,39–41] Furthermore, sweat rate,[18,42–44] thirst,[21,45–49] and fluid intake[19,20,24,43,50–55] during exercise vary greatly. Therefore, individualized fluid-maintenance recommendations need to be considered for physically active people. *Strength of Recommendation (SOR): A*

Importance of Maintaining Euhydration

2. Both severe clinical hypohydration and hyperhydration can degrade athletic performance and are potentially fatal.[34–36,38,50,56–58] Early signs and symptoms of these conditions may overlap, including
    a. Thirst
    b. General malaise
    c. Fatigue
    d. Headache
    e. Vomiting

Later signs and symptoms of hypohydration (eg, thirst, gastrointestinal cramping, heat sensations or chills) and hyperhydration (eg, extremity swelling, altered mentation, mood changes, seizure) begin to distinguish the 2 conditions, but prompt blood analysis (via point-of-care devices if available) and measurement of body weight can expedite accurate diagnosis (Table 1).[35,36,38,50,58,59] *SOR: B*

3. Hypohydration leads to increased cardiovascular stress during exercise.[7,28,60] Health care professionals should understand this fact, educate physically active individuals appropriately, and apply strategies to prevent moderate to severe hypohydration. *SOR: A*
4. Thermoregulation is compromised by hypohydration greater than 1%,[4] and the risk of exertional heat illness increases at moderate to severe levels (greater than 3%).[5,27,29,61–64] This is 1 of myriad factors known to contribute to heat illness.[65] Optimal hydration is a modifiable factor that should be attempted to help prevent the onset of heat illness. *SOR: B*
5. Exercise-associated hyponatremia is caused by excessive consumption of hypotonic fluids (including sports drinks), often combined with reduced renal water clearance, resulting in maintained or increased body weight during exercise lasting 1 hour or more. Physically active individuals should not consume fluid that exceeds their exercise-related body mass losses and should monitor their weight before and after exercise to confirm adherence.[13,34,36,66] *SOR: A*
6. Individuals should not gain body mass (or body weight) during exercise (from pre-exercise to postexercise) unless they begin activity with an unavoidable fluid deficit.[13,34–36,58,67,68] Hyperhydration confers no physiological or performance advantages and is not recommended, except in specific situations with medical oversight and when factors necessitating hyperhydration before activity (eg, lack of fluid availability during the event, known excessive sweat losses) are present. Furthermore, if hyperhydration reduces blood sodium concentrations, it can lead to EAH. *SOR: A*
7. Euhydration (+1 to –1% compared with baseline values) aids thermoregulatory control[5,7,27,28,30,60–63,69–71] and helps prevent symptoms of heat illness.[63,72] Athletic trainers should promote euhydration in this range before exercise and a body mass loss of less than 2% at the end of exercise. *SOR: A*
8. Physically active individuals should maintain euhydration (+1% to –1%) for optimal exercise performance.[3–6,62,64,73–77] *SOR: B*

Fluid Replacement

9. Preseason or pre-event education to optimize fluid balance in athletes should be directed at athletes, administrators, coaches, and event directors and should include the following[17,35,38,56,78,79]:
    a. The consequences of dehydration or fluid overload.
    b. Hydration-monitoring strategies.
    c. How to use reliable and valid measures of pre-exercise and postexercise body mass measurements to assess fluid status.
    d. How to schedule activities and modify the rules of play to optimize hydration and improve safety.
    e. Environmental influences on fluid requirements. *SOR: C*
10. Athletic trainers should educate physically active people, the parents of physically active children, and coaches about sweat rate, sweat-rate calculation, and how to develop an individualized hydration plan.[19,20,78,79] *SOR: B*
11. Athletic trainers or other health care providers should help establish individualized hydration plans for physically active people (including those involved in team

sports). The plans should include rehydration strategies that consider sweat rate, environment, acclimatization state, body size, exercise duration, exercise intensity, and individual fluid preferences and tolerance.[19,20,79] *SOR: B*

12. Gastric emptying (ie, how quickly fluids exit the stomach) is independently altered by fluid volume, osmolality, pH, carbohydrate type and concentration (if present in the fluid), exercise intensity, environmental stresses, fluid temperature, and the extent of hypohydration. Each of these variables should be considered when an individual hydration strategy is developed.[78,80–84] *SOR: B*
13. Heat acclimatization affects the fluid and electrolyte requirements of physically active people. Sweat losses increase and sweat-electrolyte concentrations decrease with heat acclimatization.[85–89] Electrolyte losses may increase or decrease depending on the relative magnitude of each of these factors. Heat acclimatization should be a factor in developing individualized fluid-replacement plans. *SOR: A*
14. Water or other palatable fluids should be easily accessible before, during, and after activity.[51,90] Athletes often prefer cool, flavored beverages; these should be available, when possible, to promote rehydration.[51,91,92] *SOR: B*
15. Physically active individuals should refuel (ie, eat and drink) within 2 hours of physical activity to replace fluid, electrolytes, carbohydrates, and protein.[11,93–106] *SOR: B*
16. Athletic trainers should develop policies that use environmental-condition guidelines to determine work-rest ratios and provide water breaks. They should communicate with coaches and administrators to implement appropriate policies.[107–110] *SOR: B*

Beverage Additives

17. The athlete's diet and rehydration beverages should include sufficient sodium (enough to replace losses but not an excessive amount) to prevent or resolve imbalances that may occur as a result of sweat and urine losses.[10,19,93,111] *SOR: B*
18. Pre-exercise sodium ingestion can expand vascular fluid volumes.[100,112] Ingesting sodium during activity delays blood sodium decreases in some people[87,88,113] but has a limited preventive effect in others.[35,58,114,115] Sodium supplementation before and during exercise should be individualized based on specific losses and needs and should be practiced. *SOR: B*
19. Caffeine may increase short-term urine production at rest but does not induce diuresis during exercise.[116–118] Athletic trainers should not discourage mild or moderate (approximately 3 mg/kg: more than a cup of coffee for a 70-kg individual) caffeine consumption before and every 30 minutes during exercise on the basis of diuretic effects.[116–121] *SOR: A*
20. Hyperhydration using glycerol is not recommended for athletes due to potential negative side effects (eg, headache, lightheadedness, nausea) and insufficient evidence of performance benefit.[122–127] *SOR: B*
21. Beverages with $\leq 4\%$ alcohol content do not dehydrate active people.[128,129] However, beverages with greater alcohol content facilitate excessive diuresis and should be discouraged for fluid replacement. *SOR: B*

Hydration Assessment

22. Calculating body mass change is a quick and effective way for the AT and other health care providers to track hydration status over the course of 24 hours.[130,131] This measure is valid only when compared with at least 3 consecutive days of euhydrated baseline average mass.[132–134] Body mass changes are also useful for assessing hydration status between practices on days with multiple workouts and can help educate athletes regarding individual fluid needs. Body mass should be used as an objective hydration measure by physically active individuals and clinicians to ensure maintenance of hydration status. *SOR: B*
23. Assessment of the first morning urine void increases the validity of hydration-status measurement.[39,135–140] Health care professionals should test the first morning urine for urine specific gravity (USG), when feasible, to evaluate hydration status. Spot urine samples at other times of the day can be confounded by fluid intake, exercise, and food intake and may not be accurate indicators of hydration status.[137] *SOR: B*
24. Personal cues are important for individuals to gauge their hydration status. Thirst sensation, void frequency, and urine color are valuable indicators over the course of a day or between days for obtaining a relative hydration assessment.[45,141] These factors should be addressed in hydration education and regarded as personal reminders for individuals in their daily hydration maintenance. *SOR: C*

Unique Situations

25. At events (eg, road races, tournaments) that carry the potential for athletes to develop hypohydration and EAH during and after competition, appropriate personnel should educate participants and staff in advance regarding fluid balance.[142–145] *SOR: B*
26. If moderate (2% to 5%) or severe (greater than 5%) hypohydration is identified, oral fluids should be administered. Only if oral fluids are not tolerated or fluid losses are ongoing (from vomiting or diarrhea) should intravenous (IV) fluids be administered by an appropriately trained and licensed medical professional. In the absence of a diagnosis beyond hypohydration, preventive IV fluids are not recommended. Administration of IV fluids for same-day return to play should be supervised by a licensed medical professional on-site who is responsible for patient health and safety.[2,146,147] *SOR: B*
27. Hypohydration and EAH are risk factors for exertional rhabdomyolysis during physical activity and both can increase its severity.[67,68,148] Athletic trainers should facilitate appropriate education and fluid availability (eg, adequate but not excessive) to help athletes maintain euhydration during physical activity. *SOR: C*
28. Hypohydration is a known predisposing factor for exertional sickling in those with sickle cell trait or disease.[59] Targeted education and hydration monitoring are warranted for an athlete known to have sickle cell trait or disease.[149–151] *SOR: B*
29. When determining an athlete's weight-class eligibility, hydration status should be assessed using a valid measure

of hydration status (eg, first voided urine osmolality or refractometer USG).[90,152–155] *SOR: B*

30. Whole-body sweat losses in children are less than in adults, and children require different rehydration plans than adults.[24,55,156–158] Hydration education is important for youth and adolescent athletes.[19,20,79] Athletic trainers should facilitate proper education based on individual needs. *SOR: B*
31. Beyond age 50 years, a person's thirst sensitivity decreases with hypohydration and urine-concentrating ability decreases.[159] Extra consideration for hydration should be directed toward these populations during physical activity.[24,159,160] *SOR: A*

LITERATURE REVIEW

Fluid Balance and Regulation

The human body maintains total body water within a narrow range to preserve homeostasis. Individual fluid consumption varies from person to person at rest and before, during, and after exercise.[1,39,40,161] Athletic trainers should promote fluid-balance habits that contribute to overall health and the reduction of injury and illness.

Water is a major component of the human body, accounting for approximately 73% of lean body mass in young adults.[162] Body water is distributed within cells (*intracellular fluid*), between cells (*interstitial fluid*), and in plasma (*intravascular fluid*). At rest, approximately 40% of the total body mass is intracellular fluid, 15% is interstitial fluid, and 5% is intravascular fluid.[163] Water movement between compartments is due to hydrostatic, osmotic (sodium and potassium), and oncotic (protein) pressures. Sweat is hypotonic relative to body water, so elevated extracellular tonicity results in water movement from the intracellular to extracellular (interstitial and intravascular) spaces. As a consequence, all water compartments can dehydrate with sweating, contributing to a total body-water deficit and hypohydration.[164,165] The resulting hypovolemic hyperosmolality is thought to precipitate many of the physiological consequences associated with hypohydration.

Importance of Maintaining Euhydration

Physiological Implications of Hypohydration. All physiological systems in the human body are influenced by hypohydration. The degree of hypohydration dictates the extent of systemic compromise. Isolating the physiological changes that contribute to systemic compromise is difficult, as an alteration in 1 system (eg, cardiovascular) influences the function of other systems (eg, thermoregulatory, muscular). In terms of thermoregulation, the body balances metabolic heat production and exogenous heat accumulation by transporting heat via the vascular system to the body surface and dissipating it via conduction, convection, evaporation, and radiation at the skin. The relative contribution of each heat-transfer mechanism depends on the environmental conditions and exercise intensity.[166–170] Evaporation is the predominant heat-loss mechanism during exercise in warm conditions.[167,171] The sweating response is therefore critical to maintaining body temperature during exercise in the heat. If water loss via sweating occurs at a greater rate than fluid consumption, dehydration ensues, affecting both sweating and heat transport from working muscles.

During exercise, the body preferentially directs intravascular fluids to (1) the brain for nutrition and oxygen delivery, (2) the heart and lungs for blood circulation and gas exchange, (3) the peripheral sweat glands and blood vessels for thermoregulation, and (4) the working muscles for nutrition and oxygen delivery.[7,30,61,71] More than 2% hypohydration causes a decrease in sweat rate and sweating onset.[64] Severe hypohydration (greater than 5%) threatens the ability to maintain normal body temperature, exercise intensity, and vital organ function. A potential consequence of hypohydration is a generally linear increase in core temperature during physical activity, with core temperature rising approximately 0.15°C to 0.20°C for every 1% of body weight lost (due to sweating) during activity.[5,28,64]

When a hypohydrated individual exercises, the added thermal strain is due to both impaired skin blood flow[64,71,172] and altered sweating responses.[28,31,61] These thermoregulatory changes may negate the physiological advantages resulting from increased fitness and heat acclimatization, both of which increase plasma volume. When combined with exercise, hypohydration decreases the sweating response, increases body temperature, and raises the overall risk of heat illness.[63,72]

Thermal strain increases *cardiovascular stress*, which is characterized by decreased stroke volume, increased heart rate, increased systemic vascular resistance, and, as strain progresses, decreased cardiac output.[7,26,28,61,64] Similar to body temperature changes, the magnitude of cardiovascular alterations is proportional to the degree of hypohydration.[7] For example, heart rate increases 3 to 5 beats per minute for every 1% decrease in body mass.[60,69] The stroke-volume reduction seen with hypohydration appears to be due to reduced central venous pressure, resulting from reduced blood volume.[7,28,30,64,71] Both hypovolemia and hypertonicity have been suggested as mechanisms for the altered thermoregulatory and cardiovascular responses during dehydration.

Additionally, hypohydration reduces heat tolerance and the time to exhaustion during exercise; the latter also occurs at lower core temperatures.[29] Furthermore, hypohydration is an etiologic factor in the onset of heat exhaustion and exertional heat stroke due to impairments in thermoregulation and cardiovascular compromise.[65] Hypohydration contributes to many conditions (eg, heat illness, cardiac dysfunction) that reduce exercise performance and safety; however, euhydration does not confer immunity to these conditions. An in-depth review of heat illness during physical activity is presented in the NATA position statement on exertional heat illnesses.[65]

Exercise-Associated Muscle Cramping. Hypohydration has been hypothesized to contribute to the onset of exercise-associated muscle cramps (EAMCs) via contracted extracellular fluid.[65] Long considered a hydration-related concern,[173] EAMCs have now also been linked to other causes.[174–177] The 2014 death of a football player who drank approximately 4 gallons of water and sports drinks to relieve cramping[178] demonstrates that replacement strategies for athletes should be strictly supervised and limited to replacement of actual losses. Education for athletes and coaches must emphasize the life-threatening risks of EAH. A more in-depth discussion of

EAMCs can be found in the NATA position statement on exertional heat illnesses.[65]

Physiological Implications of Hyperhydration. If not promptly recognized and appropriately treated, EAH is potentially fatal via cerebral or noncardiogenic pulmonary edema. This condition had been thought to be limited to endurance activities, such as marathons and the Ironman triathlon,[7] but the deaths of 2 high school football players during the 2014 season[178] emphasize the need for a better understanding of this condition beyond the scope of endurance medicine.

Although EAH occurs in 10% to 20% of sampled marathon finishers, clinically significant cases are relatively uncommon.[38,56,58,145] Significantly low serum sodium levels are identified more often in women than in men and after activity that exceeds 4 hours in duration.[38,56] When physically active individuals adequately replace sodium losses and do not consume excess fluids, EAH is prevented. Exercise-associated hyponatremia typically results from ingesting water or hypotonic beverages (including sports drinks) beyond sweat losses.[13,34,35] Often, renal water clearance is inadequate due to inappropriate arginine vasopressin release after exercise.[179] Two common, often additive scenarios are (1) ingesting water or hypotonic beverages (including sports drinks) beyond sweat losses, resulting in weight gain during exercise associated with inadequate renal water clearance,[179] and (2) large sweat sodium and water losses that are not adequately replaced or that are replaced with hypotonic fluids.[34] Exercise-associated hyponatremia likely occurs on a continuum between these opposite mechanisms.

Sweat sodium losses are generally low in heat-acclimatized athletes and probably do not play a large role in EAH except in activities lasting a very long duration.[36] Ultimately, the extracellular fluid space has a decreased solute concentration compared with the intracellular fluid space, and water flows into the cells to equalize solute concentrations across cell membranes, producing intracellular swelling. This, in turn, leads to physiological dysfunction at the cell, tissue, and organ-system levels, with most clinical signs reflecting intracranial pressure changes and reduced oxygen exchange in the lungs. Death from EAH is usually due to herniation of the brainstem.

Signs and symptoms of EAH normally present at serum sodium levels $<130\ \text{mmol}\cdot\text{L}^{-1}$ (range = 109–131 $\text{mmol}\cdot\text{L}^{-1}$)[115] and include milder early indications such as lightheadedness, dizziness, nausea, puffiness of the extremities or face, muscle cramps that do not resolve with the usual care, and body weight gain from baseline. Severe later indications include altered mental status, which may consist of disorientation, confusion, agitation, delirium, or feelings of "impending doom"; obtundation; phantom running; seizures; coma; signs of herniation, such as decorticate posturing and mydriasis; and signs of noncardiogenic pulmonary edema, such as dyspnea and frothy sputum.[35,38,56,58]

Successful treatment of EAH associated with encephalopathy involves rapid sodium replacement in sufficient amounts via hypertonic (3% or greater) saline IV infusion to increase sodium concentration in the intravascular space, which draws water from the intracellular space. For mild cases of EAH, the patient should either be observed while fluids are withheld until he or she begins to urinate or should ingest oral hypertonic fluids or salty foods to shift water into the gut. Hypovolemic hyponatremic clinical presentations are rare but have been detected in athletes participating in endurance events.[36,38] In the absence of encephalopathy, these athletes may be cautiously rehydrated with normal saline, but their serum sodium levels should be checked between liters of fluid. If encephalopathy is present, treatment with IV hypertonic saline should be initiated as described earlier.

Performance Implications of Hydration During Exercise. Scientific debate continues with respect to the apparently discordant outcomes between field-based and laboratory studies of the effects of hypohydration on exercise performance. Many laboratory studies have demonstrated a consistent association between hypohydration and decreased exercise performance.[180,181] However, when the same variables were monitored in some uncontrolled field studies, the data seemed to conflict.[182–185] When confounding variables were controlled in field studies, thermoregulation was markedly compromised, cardiovascular strain increased, and exercise performance decreased with increased levels of hypohydration.[4,5] When physical activity takes place on a field, the concepts that govern human physiological regulation of homeostasis remain valid and cannot be ignored.

Endurance Performance. In studies of prolonged aerobic activity, performance was consistently reduced when hypohydration met or exceeded 2% body mass loss.[3–5,62,74,98,181,186] Physiologically, a decrease in the available body fluid limits how much vascular volume is available for the delivery of nutrients and oxygen to working muscles and the central nervous and cardiovascular systems.[26,187] When fluids are limited during physical activity, symptoms of dehydration and decreases in performance become more apparent.

Abundant research[4,5,19,62,70,74] has documented aerobic performance decrements with hypohydration. Contradictory findings generally involved marginal levels (less than 2%) of hypohydration or a lack of exercise-intensity measures.[23,75,188] Reductions in total body water decrease stroke volume and peripheral sweat gland perfusion.[61] Therefore, in temperate and hot environments, performance is decreased when hypohydration is greater than 2% body mass.[181] It has been demonstrated, however, that in cool environments[74] or when thirst is mitigated,[23] aerobic performance can be maintained. Yet consuming fluids according to thirst alone does not maximize performance.[189] At rest, increased thirst occurs when body mass losses approach 2%.[48,50] During exercise, thirst signals at similar water-loss thresholds appear to be absent or ignored; this is referred to as *voluntary dehydration*.[47] Furthermore, despite decreased performance with hypohydration, hyperhydration provides no performance benefits during endurance activity and increases the risk of EAH.[64,190–192]

Anaerobic Performance. Strength and power are important in some team and individual sports. The multifactorial nature of these tasks makes it difficult to isolate the effects of hydration on performance. Still, when data are combined, decrements in strength, power, and anaerobic endurance are consistently apparent in athletes who are more than 2% hypohydrated.[76,193] Most studies[193,194] that have addressed the influence of hypohydration on muscle

Table 2. Sweat-Rate Equation[a]

Sweat loss (L) = Body mass before exercise (kg) – Body mass after exercise (kg) + (Volume of fluid consumed during exercise [L]) – (Urine volume, if any [L])
Sweat rate (L/h) = Sweat loss (L) / Exercise duration (h)

[a] If body mass is assessed in kilograms and fluid consumed in liters, the sweat rate = L/h.

function showed that a fluid deficit of 3% to 4% elicited a performance decrement. Anaerobic performance research related to hydration status is highly varied (eg, dehydrating protocol, performance outcome, recovery timing),[76] which makes it challenging to decipher the true mechanisms or specific levels of hypohydration that cause decrements. However, the data consistently support the likelihood that euhydration improves anaerobic performance.

Cognitive Performance. Specific and rapid information processing is necessary for quick and accurate decisions and is fundamental to many sport and military activities. Several investigations[8,9,195–198] demonstrated that a modest level of hypohydration (greater than 1%) compromised cognitive function, including task performance, reaction time, short-term memory, and mood state. Yet most impairments seem clinically negligible, and others contended that the effect of hypohydration on cognitive function was limited.[181,195,199,200] At similar hypohydration levels, women seemed to demonstrate fewer consistent cognitive impairments but more mood-state decrements than men.[8,9,139] Furthermore, heat exposure may induce a more profound negative effect of hypohydration on mood state in both men and women.[195,198,199]

Fluid Replacement

Hydration safety for physically active individuals can be influenced by body fluid status, but significant variability exists in factors such as habitual daily water intake,[1,40] sweat rate,[32,53,201] and gastrointestinal tolerance of consuming a large fluid volume during exercise,[202] which makes universal recommendations impossible. Ideally, individual sweat-rate assessments should be performed several times under realistic environmental conditions and at varying exercise intensities while wearing standard clothing and equipment specific to the sport (Table 2). Calculating an athlete's sweat rate facilitates individual education and an understanding of hydration status and fluid loss during activity that can be easily translated into an individualized fluid-replacement plan.[19,20]

With high-performance athletes, restricting dehydration to no more than 2% body mass loss helps to maintain the physiological, perceptual, and safety aspects of their exercise while aiding in exercise recovery and subsequent training sessions. Rehydration plans often need to be altered during activity, and this is an important educational component of hydration. Ideally, exercise-related body fluid losses should be replaced within a short time frame, and dietary intake should replace body fuels used during exercise. Postexercise body mass losses generally require replacement with 100% to 150% of calculated fluid losses due to fluid bolus-initiated diuresis, particularly when fluid recovery time is limited (ie, less than 4 hours).[203] When recovery time is extended to more than 12 hours, balance is achieved with ad libitum food and fluid consumption.

Most individuals can avoid fluid-balance problems by drinking when thirsty during and after exercise and eating a healthy diet. In healthy individuals, the thirst mechanism is governed by a combination of serum osmolality and intravascular pressure as the body defends blood pressure and volume. Thirst typically increases at about 2% hypohydration[50] and markedly decreases when rehydration restores this level. The 2% hypohydration threshold has little effect on overall exercise performance in recreational athletes and reduces the risk of EAH due to the overconsumption of fluids.

One anecdotal strategy used by many distance athletes in an attempt to retain fluid or prevent hyponatremia is sodium tablets.[204] Little evidence supports this practice for either hyperhydration before activity[205] or fluid retention during activity.[204] Furthermore, adverse events associated with this practice during activity are unknown.[36]

Competitive and recreational athletes who have chronic medical conditions should consult their personal physicians regarding hydration recommendations and strategies to avoid exacerbating their conditions.

Sweat-Rate Variability. Recommendations for people participating in physical activity must be individualized. For example, sweat rate can vary according to body size, environmental conditions, exercise intensity, acclimatization status, and other factors.[206] Reliable estimates of sweat losses based on some of these variables exist[32]; however, they are not valid for every person and should only be used as an estimate when specific calculations cannot be conducted. Individual recommendations on fluid replacement should be based on individual data and not population estimates. In addition, competition goals and experience must be factored into fluid-intake decision planning. A 50-year-old participating in her first marathon who has a 0.4 L/h sweat rate and a goal of finishing in 6 hours should not receive the same hydration plan as a 28-year-old elite male distance runner with a sweat rate greater than 2 L/h who is attempting a 2.25-hour finish time in the same event.

Robust individual variability exists in exercise-related fluid losses and the effect of hydration status on both performance and well-being. Sweat rates for adults (>18 years old) during exercise can range from 0.5 to 4.0 L/h,[32,43,53,201,207,208] and measured sodium losses during exercise range between 0.2 and 7.3 g/h.[34,209–212] Sweat sodium concentrations, for example, range from 10 to 100 mEq/L, and these large variations require individual replacement strategies. For athletes who have had hydration complications (hypohydration or EAH) requiring medical attention, formal assessment of sweat rate and sweat-electrolyte concentrations may be necessary to determine a safe individual replacement strategy.[78]

Fluid Intake Exclusive to Exercise. In terms of fluids, on average, free-living individuals habitually consume just over 2 L/d, with the typical range between 0.5 L/d and 4.0 L/d.[1,42] Despite large individual variations in fluid intake as well as body water volume and hydration status, biomarkers in the blood remain in a relatively tight range due to the wide normal range of urine-concentrating capacity.[39,40,213] Exercise combined with individual variability in daily fluid needs makes normal fluid intake ranges difficult to establish in athletes.[1,40]

Factors Influencing Rehydration. The degree of environmental heat stress is determined by temperature, relative humidity, wind speed, and radiant energy load, which induce physiological changes that affect rehydration recommendations. Voluntary fluid intake increases substantially when ambient temperature rises above 25°C; however, the rehydration stimulus may be partially psychological.[47–49] Individual differences in learned behavior also play a role in the rehydration process. An athlete who knows from experience that rehydrating enhances subsequent performance is more apt to consume fluid before significant dehydration occurs, so appropriate education of athletes is essential to success.[79,214]

The physical characteristics of a rehydration beverage can dramatically influence fluid replacement. Salinity, color, sweetness, temperature, flavor, carbonation, and viscosity all affect how much an individual drinks.[51,91,140] Individuals exercising in the heat will voluntarily ingest more fluid if it is chilled.[51,140] Because people ingest most of their daily fluids with meals, access to ample fluids during meals and adequate time to eat and drink will improve rehydration.[101,215]

Hydration Before Exercise. The goal of an individual hydration strategy is to maximize safety and performance during exercise. It is important to begin an exercise bout euhydrated. To ensure euhydration before activity, an athlete should be mindful of individual cues, such as thirst, body weight, urine color, and voiding frequency. Individual variability exists in each of these cues, but all can provide useful information regarding hydration levels.[40,41,130,141,210,216] Competitive athletes may benefit from subtle hyperhydration (less than 2%) before exercise to avoid more than a 2% body mass deficit during activity.[208] However, this recommendation should be pursued under medical oversight and is advised only for athletes in competitions and endurance events, when access to fluids is restricted due to remote locations, or sports in which fluid is not readily available (eg, soccer, trail races). Recreational athletes should not need to consume extra fluids before activity but should begin exercise euhydrated.

Rehydration During Exercise. During exercise, the goal for the physically active is to maintain hydration and not allow more than a 2% body mass loss.[4,5,27,217] The suggested ideal strategy for exercise performance advises limiting body mass losses to less than 2% throughout activity but not gaining weight during exercise.[36,66] To maintain euhydration during activity, an athlete should consume enough fluid to approximate personal sweat volume losses and avoid both excessive body fluid losses and overconsumption of fluids.[66,79] A sample strategy for calculating sweat loss and fluid replacement is outlined in Table 3.

Thirst may be delayed, so for competitive athletes striving to maximize performance, using a "drink when thirsty" strategy may compromise performance.[4] Therefore, every individual should know his or her personal sweat rate and develop a hydration strategy based on individual needs.[19,20,66,78,79] An appropriate strategy promotes effective training and competition while maximizing safety. However, a hydration plan may require short-term revisions during competition based on unanticipated factors (eg,

Table 3. Sample Sweat-Rate Calculations

Modifying Factor	Individual A (Recreational Tennis Player, Female, 85 kg)	Individual B (Recreational Runner, Male, 80 kg)	Individual C (Collegiate Football Player, Male, 120 kg)	Individual D (Collegiate Soccer Player, Female, 60 kg)
Wet-bulb globe temperature, °C (°F)	25 (77)	22 (71.6)	29 (84.2)	28.3 (83)
Acclimatized to heat?	Yes	No	Yes	Yes
Exercise mode	1.5 h	10-km Race (0.75 h)	2.5-h Practice	Soccer game (1.5 h)
Exercise intensity	Mild/moderate (50%)	Maximal	Intermittent maximal	Intermittent maximal
Hydration status before activity	1% Hyperhydrated (85.9 kg)	Euhydrated	Euhydrated	Euhydrated
Available breaks	When feasible	Every mile (1.6 km)	Consistent breaks	Half-time (athletic administrators should consider fluid breaks based on environmental factors)
Postexercise hydration status	−1.5% Body mass (1.3 kg)	−1% Body mass (0.8 kg)	−5% Body mass (6.0 kg)	−2.5% Body mass (1.5 kg)
Fluid consumed	0.8 L	0.4 L during race	2 L during breaks	0.5 L at half-time
Sweat rate	1.3 kg + 0.8 L/1.5 h = 1.4 L/h	0.8 kg + 0.4 L/0.75 h = 1.6 L/h	6.0 kg + 2.0 L/2.5 h = 3.2 L/h	1.5 kg + 0.5 L/1.5 h = 1.3 L/h
Recommendation for similar exercise	Drink when thirsty; may also benefit from paying attention to personal hydration cues before exercise to ensure euhydration rather than overhydration.	Doing a great job. Finished the race at 1% body mass loss.	Body mass loss is likely affecting performance and increasing heat-illness risk during activity. Increase fluid consumption and try to approximate sweat rate to avoid >2% (2.4-kg) body mass loss during activity.	Due to a lack of fluid availability, try to begin exercise 0.5% hyperhydrated and ingest a little more fluid at half-time. This will limit body mass loss and prevent >2% hypohydration at game end. Slight hyperhydration for an individual with proper oversight may be beneficial in this case.

gastrointestinal upset, discomfort, fluid availability, environmental conditions, fluid type).

If athletes do not know their individual sweat rates, drinking to thirst during activity most likely represents a safe strategy to prevent overdrinking. Drinking to thirst should also be considered when exercising athletes cannot follow their ideal plan for replacing fluids at a rate similar to their sweat rate.

Rehydration After Exercise. Rapidly replacing fluids after exercise restores euhydration, improves recovery, reduces hypohydration symptoms, and decreases postexercise fatigue.* Up to 150% of the estimated fluid deficit needs to be consumed to effectively replace fluid losses after exercise over a short recovery period (less than 4 hours).[100,101,203] This additional consumption is necessary to compensate for the postexercise diuresis induced by the large fluid load and restore normal arginine vasopressin hormone levels in blood. The exact amount of fluid needed to restore euhydration depends on solid food composition and the timing of food ingestion after exercise, as the electrolyte and water contents of meals contribute to fluid replacement and can enhance fluid retention.[215]

Beverage Additives

Under normal circumstances, physically active people consuming a well-balanced diet should not need to add specific ingredients to their fluids before, during, or after activity. As a general rule, those participating in physical activity lasting less than 1 hour should require no substances other than water.[34,220] Athletes participating in exercise sessions lasting longer than 1 hour or including intense intervals may benefit from adding carbohydrates or electrolytes (or both) to rehydration fluids, especially in extreme environments.[34,80,116,221–224] Endurance athletes may be aided by fluids containing carbohydrates and electrolytes during extended training bouts and competitions.[82,100,116,221,224–226] Individuals with much greater than average sweat sodium concentrations (greater than 60 mEq/L) and high sweat rates (greater than 2.5 L/h) may benefit from sodium supplementation in the fluids consumed during activity.[34,51] However, no evidence indicates that athletes are helped by sodium supplementation beyond individual losses. Therefore, we recommend that individual assessment of sweat-electrolyte concentrations should occur before consideration is given to supplementing.

The goal of pre-exercise nutrition and hydration is to begin exercise with adequate carbohydrate availability and body water.[222] Before physical activity, individual preferences determine hydration and diet choices.[24,52,54,213,227,228] Gastric emptying, intestinal absorption, bowel transit time, and urine frequency vary for each individual.[80,202,229,230] Competitive athletes can benefit from carbohydrate-electrolyte beverages before activity.[82,116,222,224] Physically active people eating a balanced diet with adequate calories and fluids need not add ingredients to water to maintain hydration status. Beverages that appeal to individual taste preferences may encourage individuals to drink more fluids.[54,91,231] Adding carbohydrates or electrolytes (or both, especially sodium) to the rehydration drink can help maintain blood glucose, carbohydrate oxidation, and electrolyte balance.[220,232,233] In some cases, adding protein to a sports drink may improve exercise performance.[234] Rates of gastric emptying and intestinal absorption (the primary site of fluid absorption) influence rehydration, especially during exercise.[80,84,229] Fluid volume, fluid calorie content, fluid osmolality, exercise intensity, environmental stress, and fluid temperature are important factors that determine these rates. The single most important variable may be the volume of fluid in the stomach.[84,229] Maintaining 400 to 600 mL of fluid in the stomach optimizes gastric emptying.[221,229] If carbohydrates are included in the fluid, the optimal concentration for fluid absorption is between 3% and 8%,[221] but concentrations greater than 5% to 8% may slow the rate.[221,235] Exercise at greater than 80% of $\text{V}\text{o}_2\text{max}$ may decrease the rate of gastric emptying.[229,236] Ingesting about 200 mL of fluid every 15 to 20 minutes may be ideal, but this timing can be difficult in sports with extended playing time between breaks. Lastly, the rate of gastric emptying is slowed by significant hypohydration (greater than 4%), which complicates rehydration and may increase gastrointestinal symptoms.[83,202]

To facilitate postexercise recovery, competitive athletes may require more carbohydrates or electrolytes in their diet or fluids to assist in fluid balance. Ingesting carbohydrates and protein after exercise provides substantial benefits by restoring muscle glycogen and facilitating muscle recovery,[93,96–98,237,238] and simultaneous carbohydrate and protein ingestion is better than fluid alone for muscle and blood glucose recovery.[94,95,106] However, the optimal amount of either carbohydrate or protein has yet to be determined. The overarching recommendation is to replace all fluids and nutrients that were used or lost during exercise.

Caffeine does not compromise rehydration or increase urine output when consumed in small quantities (up to 3 mg/kg) during or after exercise.[116,118,119,121] Small amounts of caffeine in a rehydration beverage should not cause harm to the physically active postexercise.

Supplements containing creatine in various forms have been studied extensively due to purported dehydration and muscle-cramping episodes in those who were actively consuming them. At recommended doses, however, creatine does not compromise hydration status.[239] Because researchers have not investigated levels above the recommended dosages, no evidence is available regarding hydration changes due to supplementation with greater amounts of creatine.

The osmolyte glycerol has been used to increase body water and potentially avoid hypohydration during events. In controlled settings, glycerol promoted fluid retention.[122–127] However, the excess fluid in the body does not confer consistent physiological or performance advantages.[192] Furthermore, the side effects of glycerol (headache, nausea, etc) are quite common and not advantageous to physical activity.[123,192,240]

Alcohol inhibits arginine vasopressin release, and beverages with an alcohol content above 2% reduce fluid retention during rehydration.[128] However, in well-hydrated individuals, rehydration with beverages containing up to 4% alcohol did not increase urine output.[129] Research[129] also suggests that the influence of hypovolemia on renal fluid retention is more potent than the diuretic effect of alcohol. Drinks with increasing alcohol content (greater

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**References 82, 84, 93, 100, 113, 146, 147, 203, 218, 219.*

than 4%) facilitate excessive diuresis and should be discouraged for fluid replacement.

Hydration Assessment

Hydration status is important yet often difficult to assess accurately and reliably in athletic settings. Measurement techniques can indicate changes in hydration status[241] but should not be used to diagnose hypohydration. An individual's hydration state is in constant flux and depends on many factors; multiple indicators are needed for adequate assessment.[66,78]

Thirst. The perception of thirst at rest is accurately quantified using the subjective thirst-sensation chart (ranging from 1 [*not thirsty at all*] to 9 [*very, very thirsty*]). This chart is widely used by researchers to support thirst-sensation measures but not to quantify hydration status. Normally, thirst increases when 2% hypohydration is approached and decreases when fluid balance is restored to a loss of less than 2%. This level may offer some protection against EAH, although current evidence provides insufficient support. Furthermore, first morning thirst is strongly correlated with hypohydration as measured by an acute change in body mass.[45]

Body Mass. Measuring acute body mass changes using a valid and reliable floor scale is an efficient hydration-assessment technique. Body mass is considered a valid measure of hydration status only when losses are acutely observed (eg, prepractice versus postpractice)[131] or compared with a valid euhydrated baseline.[181] A valid baseline generally requires 3 consecutive days of euhydrated weight assessments to establish the normal body mass that may be subject to circadian variation and depends on the individual's diet, digestion, fluid intake, and bowel habits.[131,133,216,242,243] Body mass assessment for hydration status is best used to show short-term changes between pre-exercise and postexercise or changes in status from baseline or in conjunction with other hydration measurements.

Urine Concentration. The concentration and color of urine vary inversely with its volume. As long as the first morning measurements of urine concentration are used to assess hydration, any one of them serves as an acceptable complement to body mass and thirst observations for assessing hydration.[137] An important consideration when assessing hydration is that urine volume and concentration are affected not only by fluid loss but also by activity, diet, and especially fluid intake.[137] The stability of urine concentration as a measure of hydration assessment is compromised by all of these variables. The most stable value, which provides a valid and reliable indication of hydration status, is the first morning assessment. When this is not feasible, ATs should know that urine analysis may confound the clinical decision-making process and that body mass assessment provides more reliable information.[137]

Urine color is a popular assessment technique because it is noninvasive, inexpensive, and reliable. The urine color chart (available at www.hydrationcheck.com) demonstrated good sensitivity and specificity compared with USG and osmolality measures.[41,135,136] Urine color should be assessed after a sample is collected in a clear container and then evaluated in adequate lighting without shadows. Assessing color in the toilet bowl after urination is not reliable, as the sample is diluted with water and cannot be accurately compared with the color chart. Urine color has also demonstrated effectiveness as an educational tool for athletes to assess their own fluid status.[19,20,79] Lastly, a urine color of 8 on the chart indicates gross muscle damage and myoglobin present in the urine (rhabdomyolysis or kidney dysfunction); a patient presenting with this color should receive prompt referral and follow-up testing.[135,138]

Urine specific gravity compares the concentration of a urine sample with that of distilled water and can be measured in several ways. Techniques include floating, handheld, optical, or digital refractometry as well as urine reagent strips. Urine refractometry results are valid compared with more complicated but time-tested measures of urine concentration, such as urine osmolality.[244] Refractometry is simple and requires only a small urine sample and a relatively inexpensive (less than $300) handheld device. Urine reagent strips are unreliable, even when manufactured solely for hydration assessment,[245] and are not recommended for this purpose.

Other Techniques. Additional techniques available for estimating hydration status include urine and plasma or serum osmolality assessments. However, these techniques are time sensitive and require expensive equipment not typically available in clinical or field settings.[241] An osmometer is expensive (more than $3500) and requires regular calibration and sophisticated maintenance. Although urine osmolality is more valid and reliable than other field-accessible methods,[244] its cost typically precludes use by ATs. Furthermore, obtaining a plasma or serum sample requires much more equipment (needles, tubes, centrifuge, etc) and phlebotomy training, again restricting access to these measures by ATs. It is important for the evidence-based practitioner to understand all hydration-assessment techniques and extrapolate results from only those studies that incorporated multiple measures.

For the best estimate of hydration status in an athlete, 3 simultaneous measures are recommended: first morning urine color (or USG), thirst sensation, and body mass.[137] All can be obtained in an athletic training facility with easily accessed equipment and are reliable indicators of hydration status. Body mass is best measured at the same time each morning for valid comparisons.[216] When body mass is assessed both preactivity and postactivity, individuals can be educated on specific rehydration recommendations after activity.

Recognition of Hypohydration and Fluid Overload

The early signs and symptoms of exercise-related hypohydration include thirst and general discomfort or complaints (approximately 2% body mass deficit). These are followed by flushed skin, weariness, cramps, and apathy. At greater water deficits (more than 2% body mass loss), dizziness, headache, vomiting, nausea, heat sensations on the head or neck, chills, and dyspnea may be present (Table 1).[50,57,139] The degree of hypohydration, mental status, and general medical condition of the athlete will dictate the mode, amount, type, and rate of recommended rehydration.

A potential difficulty in recognizing hydration abnormalities is that the signs and symptoms of hypohydration may overlap those of EAH (Table 1).[50,57,58,142,144] The early signs of EAH include headache, dizziness, physical exhaustion, muscular twitching, and nausea, all of which are also symptoms of hypohydration. Differential signs and symptoms of EAH due to fluid retention include weight gain, history of overdrinking, extremity swelling, and progressively worsening headache.[38,142] Signs of encephalopathy generally occur when the sodium concentration is less than 125 $\text{mEq}\cdot\text{L}^{-1}$ but have been documented with a sodium concentration of 131 $\text{mEq}\cdot\text{L}^{-1}$.[115] More severe encephalopathy is accompanied by altered mental status, pulmonary edema, collapse, unconsciousness, seizure, and coma. When these conditions cannot be differentiated based on the history and physical examination, a blood sodium measurement is needed for accurate diagnosis, which is imperative because either hypotonic or isotonic fluid given inappropriately to a patient with EAH can be fatal. If point-of-care blood sodium assessment is not available for a patient with severe encephalopathy, the empiric administration of a hypertonic sodium IV can be life saving and will not harm a dehydrated individual.[36]

Unique Situations

Event Management. Medical professionals responsible for directing, supervising, and coordinating athletic events should include hydration strategies in the medical and safety plan. This includes estimating the maximum fluid volume needed for each participant in the event to optimize both performance and safety. The event safety plan should include athlete education opportunities for understanding fluid balance and should facilitate easy access to fluids for sweat-loss replacement. The event medical staff should be trained and equipped to assess athletes for dehydration, EAH, and heat illness. Promotional and educational materials provided to participants should include basic definitions of hypohydration and hyperhydration,[142] along with strategies to avoid both EAH (overconsumption) and dehydration during the event. Event managers should consult experts in the planning stages to develop effective strategies that reflect the event participants, environmental conditions, resources, and medical support. Mass events with a high potential for participants to develop EAH or dehydration should have a detailed medical plan to appropriately differentiate EAH, hypohydration, exertional heat stroke, and exercise-associated collapse that includes point-of-care portable blood-electrolyte analysis and rectal temperature measurement before initiating treatment.[59]

Environmental Factors. The diuretic effects of moderate-altitude (greater than 2500 m) and high-altitude (greater than 3600 m) exposure have long been recognized by mountaineers as a successful adaptation to altitude whereby hemoconcentration (reduced plasma volume) improves oxygen delivery to the tissues.[246] The loss of water is self-limiting to approximately –2% of body mass and stems primarily from the stimulation of peripheral arterial chemoreceptors; the altitude-induced fluid deficit is not corrected by increased fluid consumption. In water sports (eg, swimming, water polo), diuresis occurs secondary to fluid shifts among compartments in the body induced by heat-conserving vasoconstriction.[190,246] It is important to note that hydration assessment immediately after exercise in cool water is inaccurate and must be delayed. When physical activity occurs in cold weather, the drive for thirst is blunted and ad libitum fluid consumption is decreased.[27,47,247] Furthermore, cold air (and the resulting decreased skin temperature with peripheral vasoconstriction) induces a slight diuretic effect.[33] Medical personnel involved in the care of physically active individuals in these settings should be aware of particular nuances that may affect recommendations to ensure athlete safety and performance reasons.

Intravenous Fluids. Intravenous fluids are used to correct symptomatic hypohydration when oral fluids are not tolerated or continued fluid-electrolyte losses exceed fluid intake. Such IV fluids are rarely necessary in otherwise healthy patients. Outcomes after rapid IV rehydration suggest no lasting benefits exceeding those of oral rehydration,[218,248] and hormonal and fluid balances are facilitated by the oropharyngeal reflex and swallowing.[146,147,219,249] Oral fluids are recommended as the first-line rehydration strategy for most patients with exercise-related hypohydration, although some recent evidence[146,147] suggests that recovery from hypohydration (approximately 4% body mass loss) is most efficient with the concomitant use of IV and oral fluids. When oral fluids are not tolerated (because of vomiting, extreme nausea, or excessive diarrhea), IV fluids can be used as a primary intervention. If EAH is suspected, a serum or blood sodium level should be measured before oral or IV (hypotonic or isotonic) fluid is administered.

Sickle Cell Trait and Exertional Rhabdomyolysis. Hypohydration is a known risk factor for an exertional sickling episode.[59] Hydration status should be part of the education process and then should be closely monitored in athletes known to have sickle cell disease or the sickle cell trait. To facilitate safe participation, extra care is warranted for these individuals to ensure adequate hydration status before physical activity.[59] Conversely, exertional rhabdomyolysis seems rather common in patients with EAH.[66] Although relatively novel in observation, true mechanisms have yet to be identified. Osmotic stress and excessive muscle breakdown may be related.[250] Therefore, individual euhydration maintenance should be promoted to prevent exertional sickling as well as EAH and exertional rhabdomyolysis.[36]

Weight-Certification Recommendations. Many athletes purposely dehydrate to qualify for lower weight classes (eg, wrestling, martial arts) or to meet physical appearance expectations (eg, gymnastics). To discourage this unhealthy practice, many state and national organizations require weight certification before or early in the competitive season. Unfortunately, limited agreement exists among governing bodies regarding a safe method to certify athletes in specific weight classes.[154,155,251,252] Best practice is for trained medical professionals (eg, ATs, physicians) with established independent authority and freedom from team bias to determine the appropriate weight class based on the athlete's best interest.[153] Following are recommendations for sport weight certification:

1. All measures should be assessed using the first morning urine for the most validity.[137] Use of other assessment techniques or spot urine samples may result in misclassification of hydration status.[137]

2. If USG is not <1.025 (first morning void), as quantified by a digital or clinical refractometer, body mass and body fat should not be measured. The next measurement should occur at least 24 hours later.
3. Body mass should be measured with a calibrated scale (±0.2 lb [0.1 kg]).[131,216]
4. A trained technician should measure body fat. Because some of the available clinical measures are influenced by hydration status (eg, bioelectrical impedance, skinfolds),[134,152,154,162,253] it is imperative that USG be assessed in conjunction with body mass and body fat assessment.

Due to the many potential negative consequences of rapid exercise-induced dehydration, the following practices should be strongly discouraged for the purpose of "making weight": impermeable or insulating clothing, excessive exercise in a hot environment (steam room or sauna), fluid restriction, and purposeful fasting.[66]

Aging and Hydration. Under normal conditions of daily life, fluid intake is governed by multiple factors, including thirst. Most large surveys show that daily fluid consumption is the same in healthy, independently living 65- to 80-year-old adults as in 20- to 35-year-old adults: approximately 2100–2400 mL/d.[1,40,253] However, the timing of drinking and beverage choices often vary in older adults. Less fluid is consumed in the evening hours, presumably to prevent frequent nighttime urination.[227] Dehydration in the elderly often results from clinical conditions, medication use, or accidental or disease-related fluid deprivation or losses (or a combination of these).

The sensation of thirst is blunted in many but not all older exercisers during and after exercise- or heat-induced dehydration.[227,228,254] Reduced thirst in the elderly is thought to be due to a diminished ability to sense a volume deficit (from hypotension or low blood volume) at the central level.[254] With aging, osmoregulation remains intact but central processing of signals by satiety centers in the brain may change.[254,255] Although healthy older adults eventually restore all fluid losses, this occurs at a slower rate than in younger adults.[253] This age effect is thought to be progressive, yet the rate of decline appears to be highly variable and no longitudinal data are available.

Hydration is important for master's athletes (older than 40 years) during the first 5 days of heat acclimatization, when plasma volume expansion occurs. This plasma volume expansion requires increased fluid intake. Two studies[159,160] examining plasma volume expansion during early heat acclimation showed that many active adults over age 50 may not adequately acclimate to exercise-heat stress due to inadequate postexercise and 24-hour fluid intake.

SUMMARY

This position statement is intended to provide clinical ATs with evidence-based hydration recommendations for physically active people. Individual safety and performance are optimized when body mass losses are limited throughout activity to 2% or less without total body water gains from baseline. Competitive athletes striving for maximal performance may benefit from a strategy based on replacing sweat losses during prolonged activity. To reduce the risk of EAH, athletes and recreational exercisers should only replace fluid lost in sweat during exercise and not gain fluid weight. Exercise performance during intense or long-duration events may be improved by adding carbohydrates and electrolytes to rehydration beverages. Replacement fluids may be more palatable for athletes when chilled and when small amounts of sodium and flavoring are added. Education strategies for physically active people should address personal sweat rates, hydration cues, and rehydration strategies that avoid both hypohydration and fluid overload. These strategies will help prevent hypohydration and EAH, maximize safety during physical activity, and optimize exercise performance.

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