Hydration for Health and Performance — In Plain Language

There are many official *position stands on hydration and physical activity* that have been issued by a variety of professional organizations such as the American College of Sports Medicine (ACSM), the National Athletic Trainers Association (NATA), the American Academy of Pediatrics (AAP), and the International Association of Athletics Federations (IAAF). Each of these documents contains valuable scientific and practical guidance for anyone who is physically active and works up a sweat.

Unfortunately, science-based recommendations are often obtuse and confusing. Scientific position stands are typically written by scientists for scientists and often lack the clarity and brevity that appeal to nonscientists such as coaches, athletes, and a variety of sports health practitioners, including athletic trainers, strength and conditioning coaches, personal trainers, and registered dietitians.

This document addresses the practical aspects of *hydration for health and performance* in a way that provides clear, science-based clarification, along with selected references in support of each statement. The intent of doing so was to create an easy-to-read reference document that satisfies the desire for simple, clear recommendations coupled with very brief science-based explanations. The references provided are meant to be representative of the supporting science, a starting point for anyone who wishes to learn more. There are many other references that could have been cited, but I kept the citations to a minimum for the sake of brevity.

SECTIONS

GENERAL HYDRATION RECOMMENDATIONS

✓ **For good health and to protect physical and mental performance, it is always better to be well hydrated than dehydrated. This is true for athletes of all ages, as well as workers, first responders, soldiers, and physically active consumers.**

In most people, water comprises 60% or more of body weight. That simple fact is a clear reminder of the importance of water to human health. We often think of water as a solvent in which all the other molecules in the body are dissolved or suspended, or as a volumetric agent that sustains the shape and form of the body. In truth, water is so much more. In fact, *water is the most biologically important molecule in the human body* because it performs a multitude of different functions such as being an integral part of the structure and function of enzymes. So it should not be surprising that staying well hydrated gives us the best chance for optimal physical and mental function, along with helping to sustain good health across our lifespans.

- Allen MD, Springer DA, Burg MB et al. Suboptimal hydration remodels metabolism, promotes degenerative diseases, and shortens life. *JCI Insight*. 2019;4(17):1-17.
- Benelam B, Wyness L. Hydration and health: a review. *Nutr Bulletin*. 2010;35:3-25.
- Liska D, Mah E, Brisbois T, Barrios PL, Baker LB, Spriet LL. Narrative review of hydration and selected health outcomes in the general population. *Nutrients*. 2019;11(1):1-29.
- Manz F. Hydration and disease. *J Am Coll Nutr*. 2007;26(5):535S-541S.
- Perrier ET, Armstrong LE, Bottin JH, et al. Hydration for health hypothesis: a narrative review of supporting evidence. *Eur J Nutr*. 2020;60(3):1167-1180.
- Stookey JD, Kavouras S, Suh H, Lang F. Underhydration Is associated with obesity, chronic diseases, and death within 3 to 6 Years in the U.S. population aged 51-70 years. *Nutrients*. 2020;12(4):1-29.

✓ **Staying well hydrated is important to overall health.**

Water is the most biologically important molecule in the human body because it is essential for virtually every physiological and metabolic function. Not surprisingly, chronic dehydration has been linked with poor health outcomes, accelerated aging, and early death.

- Dmitrieva NI, Gagarin A, Liu D, Wu CO, Boehm M. Middle-age high normal serum sodium as a risk factor for accelerated biological aging, chronic diseases, and premature mortality. *EBioMedicine*. 2022:1-13.
- Institute of Medicine. Dietary Reference Intakes for Water, Potassium, Sodium, Chloride, and Sulfate. National Academies Press; 2004.
- Perrier ET, Armstrong LE, Bottin JH et al. Hydration for health hypothesis: a narrative review of supporting evidence. *Eur J Nutr*. 2020;60(3):1167-1180.
- Stookey JD, Kavouras S, Suh H, Lang F. Underhydration Is associated with obesity, chronic diseases, and death within 3 to 6 Years in the U.S. population aged 51-70 years. *Nutrients*. 2020;12(4):1-29.

✓ **Daily fluid needs vary widely among people. Current recommendations in the U.S. are for females to consume 2.7 liters (quarts) each day and males to consume 3.7 liters (quarts) each day.**

These recommended values are median values from survey data, not strict guidelines. Research does show that those who consume these volumes of fluid will be well hydrated, but in individual cases, doing so may result in over- or under-hydration. Body size, environmental conditions, activity level, and sweat loss combine to dictate daily fluid requirements, which can fluctuate widely from day to day.

- Institute of Medicine. Dietary Reference Intakes for Water, Potassium, Sodium, Chloride, and Sulfate. National Academies Press; 2004.
- Perrier ET, Armstrong LE, Bottin JH et al. Hydration for health hypothesis: a narrative review of supporting evidence. *Eur J Nutr*. 2020;60(3):1167-1180.
- Seal AD, Colburn AT, Johnson EC et al. Total water intake guidelines are sufficient for optimal hydration in United States adults. *Eur J Nutr*. 2023;62(1):221-226.

✓ **Most fluid consumption during the day occurs with meals and in other sedentary settings, not as a result of thirst, so it is important not to restrict fluid intake during those occasions.** Thirst is not a major driver of fluid consumption during a typical day. Most fluid consumed during the day occurs as a result of *spontaneous drinking* during meals, meetings, and social gatherings. Considering the importance of being well hydrated prior to intense activity, consuming ample fluids during the day should be a constant goal.

- Chapelle L, Tassignon B, Rommers N, Mertens E, Mullie P, Clarys P. Pre-exercise hypohydration prevalence in soccer players: a quantitative systematic review. *Eur J Sport Sci*.2019;20(6):744-755.
- Institute of Medicine. Dietary Reference Intakes for Water, Potassium, Sodium, Chloride, and Sulfate. National Academies Press; 2004.
- Klimesova I, Krejci J, Botek M, et al. Prevalence of dehydration and the relationship with fluid intake and self-assessment of hydration status in Czech First League soccer players. *J Hum Kinetics*. 2022;82:101-110.
- Mattausch NR, Domnik K, Koehler K, Schaenzer W, Braun H. Case Study: Hydration intervention improves pre-game hydration status in female collegiate soccer players. *Int J Sport Nutr Exerc Metab*. 2017;27(5):475-481.

✓ **Gauging hydration status during the day can be accomplished in a handful of simple ways.** To reduce the risk of day-to-day dehydration, it is helpful to be able to gauge hydration status. Keeping an eye on the color of urine is one way; urine color should be more like lemonade than apple juice). Another method is to count the number of bathroom stops each day after the first void (a minimum of 5 for children, 7 for adults). An additional way to estimate hydration status is to, upon awakening, assess thirst, urine color, and body weight (if thirst is present, urine is dark, and body weight is lower than the day before, dehydration is likely). Measures of urine specific gravity or osmolality can also aid in tracking hydration status.

- Adams JD et al. Combining urine color and void number to assess hydration in adults and children. *Eur J Clin Nutr*. 2021;75(8):1262-1266.
- Barley OR, Chapman DW, Abbiss CR. Reviewing the current methods of assessing hydration in athletes. *J Int Soc Sports Nutr*. 2020;17(1):1-13.
- Burchfield JM et al. 24-h Void number as an indicator of hydration status. *Eur J Clin Nutr*. 2015;69(5):638-41.
- Cheuvront SN, Kenefick RW. Am I Drinking enough? Yes, no, and maybe. *J Am Coll Nutr*. 2016;35(2):185-92.

✓ **Staying well hydrated helps support skin health.** Skin is the largest organ in the human body and its outermost layer—the stratum corneum—as well as some deeper layers, appear to be positively affected by increased daily fluid intake, especially in those individuals with chronically low daily fluid consumption. Although research in this area is sparse, the existing scientific literature indicates improvements in skin hydration, dryness, roughness, and elasticity when daily fluid intake increases to recommended levels (2.0-2.7 L/day in females; 2.5-3.7 L/day in males).

- Akdeniz M, Tomova-Simitchieva T, Dobos G et al. Does dietary fluid intake affect skin hydration in healthy humans? A systematic literature review. *Skin Res Technol*. 2018;24(3):459-465.
- Liska D, Mah E, Brisbois T et al. Narrative review of hydration and selected health outcomes in the general population. *Nutrients*. 2019;11(1):1-29.
- Palma ML, Monteiro C, Tavares L et al. Relationship between the dietary intake of water and skin hydration. *Biomed Biopharm Res*. 2012;9(2):173-181.

AGE, SEX, AND HYDRATION

✓ **Children sweat less than adults and do not need to drink as much during physical activity.** Before puberty, children sweat less than adults, the sweat drops are smaller, and sweating covers less of the body surface. As with adults, increased fitness and acclimation to the heat will increase the sweating response in children, although still not to the level seen after puberty. As a result of lower sweat loss, children do not need to drink as much during physical activity as adults, making it easier for children to stay well hydrated, provided palatable fluids are made available to them.

- Falk B, Bar-Or O, R C, MacDougall D. Sweat gland response to exercise in the heat among pre-, mid-, and late-pubertal boys. *Med Sci Sports Exerc*. 1992;24(3):313-319.
- Falk B, Dotan R. Temperature regulation and elite young athletes. *Med Sport Sci*. 2011;56:126-149.
- Meyer FM, Bar-Or O, MacDougall D, Heigenhauser GJ. Sweat electrolyte loss during exercise in the heat: effects of gender and maturation. *Med Sci Sports Exerc*. 1992;24(7):776-781.

✓ **Children's academic performance can benefit from staying well hydrated.** Even at rest, dehydration can have adverse effects on body functions and that is especially true for certain cognitive functions. The scientific evidence suggests that dehydration in excess of 2% of body weight negatively affects attention and mood, causes confusion, and increases the sensation of thirst, all of which can disrupt a child's ability to concentrate and learn.

- D'Anci KE, Constant F, Rosenberg IH. Hydration and cognitive function in children. *Nutr Rev*. 2006;64(10):457-464.
- Edmonds CJ, Burford D. Should children drink more water?: The effects of drinking water on cognition in children. *Appetite*. 2009;52(3):776-779.
- Wittbrodt MT, Millard-Stafford M. Dehydration impairs cognitive performance: a meta-analysis. *Med Sci Sports Exerc*. 2018;50(11):2360-2368.

✓ **Males and females have similar sweating and hydration-related responses to physical activity.** Although there seem to be differences in some fluid-regulatory hormones and in regional sweating rates between females and males, there are more similarities than differences between sexes in overall sweating responses, voluntary drinking, and rehydration.

- Baker LB. Physiology of sweat gland function: The roles of sweating and sweat composition in human health. *Temperature (Austin)*. 2019;6(3):211-259.
- Logan-Sprenger HM, Heigenhauser GJF, Killian KJ, Spriet LL. Effects of dehydration during cycling on skeletal muscle metabolism in females. *Med Sci Sports Exerc*. 2012;44(10):1949-1957.
- Logan-Sprenger HM, Heigenhauser GJF, Jones GL, Spriet LL. Increase in skeletal-muscle glycogenolysis and perceived exertion with progressive dehydration during cycling in hydrated men. *Int J Sport Nutr Exerc Metab*. 2013;23:220-229.
- Sollanek KJ, Tsurumoto M, Vidyasagar S, Kenefick RW, Cheuvront SN. Neither body mass nor sex influences beverage hydration index outcomes during randomized trial when comparing 3 commercial beverages. *Amer J Clin Nutr*. 2018;107(4):544-549.
- Smith CJ, Havenith G. Body mapping of sweating patterns in athletes: a sex comparison. *Med Sci Sports Exerc*. 2012;44(12):2350-61.

✓ **Older individuals can be at increased risk of dehydration because thirst is a less-sensitive gauge of fluid needs as we age.**
Even in young people, thirst is an inaccurate gauge of fluid needs during physical activity. As we age, thirst sensitivity declines even further, increasing the risk of dehydration and cardiovascular strain in older adults at rest and during exercise. This risk is particularly elevated during heat exposure. Whenever dehydration occurs, blood volume falls and the osmolality of the blood rises. These changes are sensed by osmoreceptors and baroreceptors that activate the release of ADH (antidiuretic hormone; vasopressin) from the brain and turn on the renin-angiotensin-aldosterone system in the kidneys to conserve sodium. These various hormones are responsible for the sensation of thirst and the reabsorption of water and sodium in the kidneys. When dehydrated, older adults (e.g., > 70 years) tend to feel less thirsty and drink less fluid compared to younger adults. This difference appears to be due to a less-sensitive baroreceptor (volume receptor) response to dehydration in older adults.

- Greenleaf JE. Problem: thirst, drinking behavior. and involuntary dehydration. *Med Sci Sports Exerc*. 1992;24(6):645-656.
- Kenney WL, Chiu P. Influence of age on thirst and fluid intake. *Med Sci Sports Exerc*. 2001;33(9):1524-32.
- Thornton SN. Thirst and hydration: physiology and consequences of dysfunction. *Physiol Behav*. 2010;100(1):15-21.

✓ **Staying well hydrated during heat waves is particularly important for older adults. Proper hydration helps keep the body cooler and supports cardiovascular function.**
During heat waves, when dehydration is combined with the reduced cardiovascular response to heat exposure that also occurs with age, older adults—especially those with existing heart and lung diseases—are at increased risk of life-threatening events created by heat stress.

- Jacobson L, Oliveira BFA, Schneider R, Gasparrini A, Hacon SS. Mortality risk from respiratory diseases due to non-optimal temperature among Brazilian elderlies. *Int J Environ Res Public Health*. 2021;18(11):1-14.
- Kenney WL, Craighead DH, Alexander LM. Heat waves, aging, and human cardiovascular health. *Med Sci Sports Exerc*. 2014;46(10):1891-9.
- van Steen Y, Ntarladima AM, Grobbee R, Karssenberg D, Vaartjes I. Sex differences in mortality after heat waves: are elderly women at higher risk? *Int Arch Occup Environ Health*. 2019;92(1):37-48.

✓ **Fluid balance during and after physical activity is not influenced by the menstrual cycle.**
The hormonal changes associated with the menstrual cycle do influence body water content, core temperature, and thirst, but not in ways that appear to make an appreciable difference in how females maintain fluid balance during or after physical activity. This topic deserves more study and future research may offer a different conclusion.

- Freemas JA, Goss CS, Ables R, et al. Fluid regulation during physical work in the heat is not meaningfully modified by the menstrual cycle when fluids are freely available. *J Appl Physiol*. 2023;doi:10.1152/japplphysiol.00580.2022
- Giersch GEW, Colburn AT, Morrissey MC, et al. Effects of sex and menstrual cycle on volume-regulatory responses to 24-h fluid restriction. *Amer J Physiol*. 2020;319(5):R560-R565.
- Maughan RJ, McArthur M, Shirreffs SM. Influence of menstrual status on fluid replacement after exercise induced dehydration in healthy young women. *Brit J Sports Med*. 1996;30(1):41-47.

MINIMIZING DEHYDRATION DURING PHYSICAL ACTIVITY

✓ **Remaining well hydrated reduces physical and mental strain, and makes exercise feel easier.**
Hydration status (fluid balance; fluid homeostasis) influences every physiological system in the human body because all systems rely upon sufficient water content for optimal function. During physical activity, sweating can cause body water content to fall. That dehydration (hypohydration) compromises physiological functions throughout the body. Staying well hydrated (euhydration) during physical activity supports important physiological functions, keeping heart rate and body temperature from rising too high and preventing muscle blood flow and exercise intensity from dropping too low. Proper hydration also benefits brain function, helps maintain mental focus, and can make exercise feel easier than it would when dehydrated.

- Ganio MS, Armstrong LE, Casa DJ, et al. Mild dehydration impairs cognitive performance and mood of men. *Br J Nutr*. 2011;106(10):1535–1543.
- Grego F, Vallier JM, Collardeau M, Rousseu C, Cremieux J, Brisswalter J. Influence of exercise duration and hydration status on cognitive function during prolonged cycling exercise. *Int J Sports Med*. 2005;26(1):27–33.
- Logan-Sprenger HM, Heigenhauser, GJF, Jones GL, Spriet LL. Increase in skeletal-muscle glycogenolysis and perceived exertion with progressive dehydration during cycling in hydrated men. *Int J Sport Nutr Exerc Metab*. 2013;23:220-229.
- Nuccio RP, Barnes KA, Carter JM, Baker LB. Fluid balance in team sport athletes and the effect of hypohydration on cognitive, technical, and physical performance. *Sports Med.* 2017;47(10):1951-1982.

✓ **Staying well hydrated decreases the risk of heat illnesses such as heat exhaustion and heat stroke.**
Body temperature naturally rises during physical activity, a byproduct of the heat produced during muscle contractions. When physical activity is combined with warm or hot environmental temperatures, the rise in body temperature can become excessive, leading to heat exhaustion or, in the most severe circumstances, heat stroke. Becoming dehydrated due to sweat loss or inadequate drinking increases the risk of heat illness because dehydration makes it more difficult for the body to lose heat. One of the most important health and performance benefits of staying well hydrated is to ensure that body temperature does not rise too high. Proper hydration supports heat loss from the body by helping maintain blood volume (dehydration causes blood volume to fall) and thereby helps maintain the delivery of blood and heat to the skin, where heat is lost through the evaporation of sweat and by radiation and convection to the environment.

- Lee JKW, Tan B, Ogden HB, Chapman S, Sawka MN. Exertional heat stroke: nutritional considerations. *Exp Physiol*. 2022;1-14.
- Periard JD, DeGroot D, Jay O. Exertional heat stroke in sport and the military: Epidemiology and mitigation. *Exp Physiol*. 2022;1-11.
- Roberts WO, Armstrong LE, Sawka MN et al. ACSM expert consensus statement on exertional heat illness: recognition, management, and return to activity. *Curr Sports Med Rep*. 2023;22(4):134-149.

✓ **Staying well hydrated improves performance capacity, especially during physical activity in warm and hot environments.**
It does not take much in the way of increased environmental temperature to impair physical performance. As body temperature rises, so must blood flow to the skin to aid in heat loss. Whenever blood is diverted to the skin, its delivery elsewhere has to decline and our bodies are programmed to reduce blood flow to the gut (stomach, intestines, kidneys, etc.) That reduction allows for ample blood to flow to the lungs, active muscles, skin, and the brain, but whenever dehydration occurs, the total volume of blood is reduced and so is blood flow to those vital tissues. Staying well hydrated ensures that blood flows where it is needed most, avoiding the inevitably impaired performance that occurs whenever physical activity, warm temperatures, and dehydration combine.

- Cheuvront SN, Kenefick RW. Personalized fluid and fuel intake for performance optimization in the heat. *J Sci Med Sport.* 2021;24(8):735-738.

- Periard JD, Eijsvogels TMH, Daanen HAM. Exercise under heat stress: thermoregulation, hydration, performance implications, and mitigation strategies. *Physiol Rev*. 2021;101(4):1873-1979.
- van den Heuvel AMJ, Haberley BJ, Hoyle DJR et al. Hyperthermia and dehydration: their independent and combined influences on physiological function during rest and exercise. *Eur J Appl Physiol.* 2020;120(12):2813-2834.

✓ **The goal of drinking during physical activity is to minimize the dehydration that can result from sweating.**

Dehydration of as little as a 1% loss in body mass is associated with altered physiological function and impaired performance, especially during exercise in the heat or at altitude. Consequently, minimizing dehydration by consuming fluids during exercise will help sustain important cardiovascular and metabolic functions and protect against decrements in physical performance. Athletes should choose whichever hydration strategy works best to minimize dehydration. Drinking to thirst, drinking ad libitum, or following a personalized hydration schedule can all be effective depending upon the athlete and the exercise circumstances (e.g., duration, intensity, environmental conditions, etc.)

- Armstrong LE. Rehydration during endurance exercise: challenges, research, options, methods. *Nutrients*. 2021;13(3):1-21.
- Cheuvront SN, Kenefick RW. Personalized fluid and fuel intake for performance optimization in the heat. *J Sci Med Sport.* 2021;24(8):735-738.
- Trangmar SJ, Gonzalez-Alonso J. Heat, hydration and the human brain, heart and skeletal muscles. *Sports Med*. 2019;49(1):S69-S85.

✓ **To experience the benefits of being well hydrated, drink enough during physical activity to minimize the amount of weight lost during that activity.**

Staying well hydrated during physical activity is the easiest, most effective, and least-expensive way to protect performance. Dehydration disrupts normal cardiovascular function, raises body temperature, reduces blood flow to muscles, and causes exercise to feel more difficult. Drinking enough to minimize dehydration helps to limit those negative responses.

- Baker LB, Lang JA, Kenney WL. Change in body mass accurately and reliably predicts change in body water after endurance exercise. *Eur J Appl Physiol*. 2009;105(6):959-967.
- Murray B. Hydration and physical performance. *J Amer Coll Nutr*. 2007;26(5):542S-548S.
- Thomas TD, Erdman KA, Burke LM. Nutrition and athletic performance. *Med Sci Sports Exerc*. 2016;48(3):543-568.

✓ **Sweat rates vary widely among people. To remain hydrated, those who sweat a lot should drink more during physical activity than those who sweat less.**

The variation in sweating rates among people is enormous. Some people's sweating rates are low, less than 1 quart (roughly 1 liter) per hour. Others have sweating rates well in excess of 2 quarts/hour. Genetics, fitness level, heat acclimation, clothing/equipment, exercise intensity, and environmental conditions combine to dictate the rate at which we sweat. To prevent significant dehydration during physical activity, those who sweat more must drink more.

- Cheuvront SN, Kenefick RW. Personalized fluid and fuel intake for performance optimization in the heat. *J Sci Med Sport.* 2021;24(8):735-738.
- Kenefick RW. Fluid intake strategies for optimal hydration and performance: planned drinking vs. drinking to thirst. *Sports Sci Exchange*. 2018;29(182):1-6.
- Rivera-Brown AM, Quinones-Gonzalez JR. Normative data for sweat rate and whole-body sodium concentration in athletes indigenous to tropical climate. *Int J Sport Nutr Exerc Metab*. 2020:1-8.

✓ **As we become fitter and accustomed to physical activity in warm/hot environments, sweating rates increase. As a result, we have to drink more to stay well hydrated.**
One of the many physiological and metabolic changes that occurs during the process of acclimating to hot weather is an increase in the onset, distribution, and volume of sweating. Sweating sooner, sweating over more of the skin surface, and sweating more all contribute to keeping core body temperature from rising too high, too quickly. Because the rate of sweating increases with heat acclimation, so must the rate at which fluids are consumed during physical activity to prevent dehydration. Whenever we sweat more, we have to drink more to minimize dehydration and thereby sustain normal cardiovascular and thermoregulatory functions.

- Alabdulwahed S, Galan-Lopez N, Hill T, et al. Heat adaptation and nutrition practices: athlete and practitioner knowledge and use. *Int J Sports Physiol Perform*. 2022;17(7):1011-1024.
- Brown HA, Topham TH, Clark B, et al. Seasonal heat acclimatisation in healthy adults: a systematic review. *Sports Med*. 2022;52:2111-2128.
- Ravanelli N, Coombs G, Imbeault P, Jay O. Thermoregulatory adaptations with progressive heat acclimation are predominantly evident in uncompensable, but not compensable, conditions. *J Appl Physiol (1985)*. 2019;127(4):1095-1106.

✓ **Weighing before and then again after a typical exercise session can help gauge if enough fluid was consumed to minimize weight loss. Weight loss of more than 2% of body weight is an indication to drink more during similar circumstances in the future. Weight gain is a clear indication to drink less.**
Whenever there is a concern that dehydration during physical activity may impair performance, steps should be taken to reduce that risk by advising athletes, workers, soldiers, and others to weigh themselves before and after exercise. That is the simplest way to determine the effectiveness of drinking during exercise.

- Kenefick RW, Cheuvront SN. Hydration for recreational sport and physical activity. *Nutr Rev*. 2012;70(Suppl 2):S137-42.
- Murray B. Hydration and physical performance. *J Amer Coll Nutr*. 2007;26(5):542S-548S.
- Thomas TD, Erdman KA, Burke LM. Nutrition and athletic performance. *Med Sci Sports Exerc*. 2016;48(3):543-568.

✓ **There are many occasions when overall sweat loss is so low that drinking during physical activity is not necessary. This is particularly true whenever sweating rates are less than 32 oz (1 quart; 1 liter)/hour.**
Drinking during physical activity is only necessary when sweat loss is enough to result in a loss of 2% of body weight (1% in the heat or at altitude). For a 155-lb (70-kg) athlete, that amounts to a loss of roughly 3 lb (1.4 kg) of body weight, the equivalent of 48 oz (1.4 L) of fluid. To lose that volume of fluid during one hour of exercise would require a sweating rate well in excess of 1 quart (liter)/hour.

- Armstrong LE. Rehydration during endurance exercise: challenges, research, options, methods. *Nutrients*. 2021;13(3):1-21.
- Cheuvront SN, Kenefick RW. Personalized fluid and fuel intake for performance optimization in the heat. *J Sci Med Sport*. Aug 2021;24(8):735-738.
- Thomas TD, Erdman KA, Burke LM. Nutrition and athletic performance. *Med Sci Sports Exerc*. 2016;48(3):543-568.

✓ **During very prolonged exercise (e.g., > 2 hours), the goal of fluid replacement should still be to minimize dehydration, but also allow for a small loss of body weight that reflects the losses that are not associated with sweating.**

The loss in body weight that is experienced during very prolonged exercise comes from both sweat and non-sweat sources. Those non-sweat sources include the loss of muscle glycogen, oxidation of body fat, and respiratory water loss. Non-sweat losses are estimated to be 0.2 grams per calorie (kcal) of energy expended. For instance, if an athlete expends 4500 kcal during prolonged training or competition, non-sweat losses would be estimated as 0.2 x 4500 or 900 grams, approximately 30 ounces (almost 2 lb). Ideally, if that same athlete fully replaced the water lost in sweat, a 2-lb loss in body weight should still occur to prevent over-hydration and reduce the risk of hyponatremia.

- Cheuvront SN, Montain SJ. Myths and methodologies: making sense of exercise mass and water balance. *Exp Physiol*. 2017;102(9):1047-1053.
- Maughan RJ, Shirreffs SM, Leiper JB. Errors in the estimation of hydration status from changes in body mass. *J Sports Sci*. 2007;25(7):797-804.
- Tam N, Nolte HW, Noakes TD. Changes in total body water content during running races of 21.1 km and 56 km in athletes drinking ad libitum. *Clin J Sport Med.* 2011;21(3):218-225.

✓ **A loss of 2% or more of body weight has been shown to consistently reduce performance capacity. However, during hot weather and at altitude, a loss of only 1% of body weight can impede performance.**

Dehydration causes widespread disruption in cardiovascular, thermoregulatory, metabolic, and brain functions that combine to impair exercise performance and some aspects of cognitive function. Dehydration of 2% of body weight is sufficient to create the conditions in which performance is diminished. When additional stressors such as warm temperatures or altitude are also present, dehydration of only 1% of body weight is enough to alter physiological responses and reduce performance capacity.

- Cheuvront SN, Kenefick RW, Montain SJ, Sawka MN. Mechanisms of aerobic performance impairment with heat stress and dehydration. *J Appl Physiol*. 2010;109:1989-1995.
- Logan-Sprenger HM, Heigenhauser GJF, Killian KJ, Spriet LL. Effects of dehydration during cycling on skeletal muscle metabolism in females. *Med Sci Sports Exerc*. 2012;44(10):1949-1957.
- Murray B. Hydration and physical performance. *J Amer Coll Nutr*. 2007;26(5):542S-548S.

✓ **Whenever a large sweat loss is expected, begin physical activity with the stomach comfortably full of fluid. This is especially helpful when fluid intake during physical activity will be limited.**

It is sometimes difficult to consume enough fluid during physical activity to offset sweat loss and minimize dehydration. In those circumstances, beginning exercise with fluid (water, sports drink) already in the stomach helps maintain rapid gastric emptying and serves to replace some of the initial sweat loss.

- Costa RJS, Miall A, Khoo A, et al. Gut-training: the impact of two weeks repetitive gut-challenge during exercise on gastrointestinal status, glucose availability, fuel kinetics, and running performance. *Appl Physiol Nutr Metab*. 2017;42(5):547-557.
- Martinez IG, Mika AS, Biesiekierski JR, Costa RJS. The effect of gut-training and feeding-challenge on markers of gastrointestinal status in response to endurance exercise: a systematic literature review. *Sports Med*. 2023;doi: 10.1007/s40279-023-01841-0
- Murray R. The effects of consuming carbohydrate-electrolyte beverages on gastric emptying and fluid absorption during and following exercise. *Sports Med*. 1987;4(5):322-351.
- Murray R. Training the gut for competition. *Curr Sports Med Reports*. 2006;5:161-164.

✓ **Consuming foods and fluids that contain sodium and other electrolytes can aid hydration prior to physical activity.**
Staying well hydrated throughout the day and especially prior to vigorous physical activity, can help sustain important physiological functions and performance capacity. Electrolytes (minerals) such as sodium, potassium, calcium, and magnesium are normally distributed in balanced fashion inside and outside all the cells in the body. Electrolytes play numerous roles in physiological and metabolic functions, one of which is to help maintain fluid balance by providing an osmotic influence that retains and distributes water molecules throughout the body. Ingesting foods and fluids that contain electrolytes helps ensure proper hydration and fluid balance.

- Maughan RJ, Watson P, Cordery PA, et al. A randomized trial to assess the potential of different beverages to affect hydration status: development of a beverage hydration index. *Amer J Clin Nutr*. 2016;103:717-723.
- Shirreffs SM, Armstrong LE, Cheuvront SN. Fluid and electrolyte needs for preparation and recovery from training and competition. *J Sports Sci*. 2004;22(1):57-63.
- Sims ST, van Vliet L, Cotter JD, Rehrer NJ. Sodium loading aids fluid balance and reduces physiological strain of trained men exercising in the heat. *Med Sci Sports Exerc*. 2007;39(1):123-30.

✓ **Before training sessions or competitions when large sweat losses are expected, ensure being well hydrated before exercise by consuming roughly 2–4 ml per pound of body weight in the 2 to 4 hours before exercise (e.g., 300—600 ml [10-20 oz] for a 150-lb person.)**
Being well hydrated prior to physical activity that causes profuse sweating delays the onset of dehydration and helps sustain cardiovascular and thermoregulatory functions.

- Burke LM, Castell LM, Casa DJ, et al. International Association of Athletics Federations Consensus Statement 2019: Nutrition for Athletics. *Int J Sport Nutr Exerc Metab*. 2019:1-12.
- McDermott BP, Anderson SA, Armstrong LE, et al. National Athletic Trainers' Association Position Statement: Fluid Replacement for the Physically Active. *J Athl Train*. Sep 2017;52(9):877-895.
- Thomas TD, Erdman KA, Burke LM. Nutrition and athletic performance. *Med Sci Sports Exerc*. 2016;48(3):543-568.

✓ **When exercise duration is brief (e.g., less than 1 hour) and sweat loss is minimal, drinking to thirst with plain water is often enough to remain adequately hydrated.**
There are many occasions when sweat loss is not great enough to result in enough dehydration to degrade performance. When that is the case, drinking to thirst, drinking ad libitum, or not drinking at all are viable options.

- Armstrong LE. Rehydration during endurance exercise: challenges, research, options, methods. *Nutrients*. 2021;13(3):1-21.
- Cheuvront SN, Kenefick RW. Personalized fluid and fuel intake for performance optimization in the heat. *J Sci Med Sport*. 2021;24(8):735-738.
- Hess HW, Tarr ML, Baker TB, Hostler D, Schlader ZJ. Ad libitum drinking prevents dehydration during physical work in the heat when adhering to occupational heat stress recommendations. *Temperature*. 2022;9(3):292-302.

✓ **Whenever performance is important in training and competition, staying well hydrated is best achieved by following a fluid-replacement plan based upon individual hydration needs.**
Knowing how much fluid is required during physical activity to minimize dehydration is the easiest way to protect against impaired performance. For example, if an athlete loses 2 lb of sweat during an hour of exercise, drinking 8 oz (~ 240 ml) every 15 minutes will keep dehydration at a minimum.

- Armstrong LE. Rehydration during endurance exercise: challenges, research, options, methods. *Nutrients*. 2021;13(3):1-21.
- McDermott BP, Anderson SA, Armstrong LE, et al. National Athletic Trainers' Association Position Statement: Fluid Replacement for the Physically Active. *J Athl Train*. 2017;52(9):877-895.
- Thomas TD, Erdman KA, Burke LM. Nutrition and athletic performance. *Med Sci Sports Exerc*. 2016;48(3):543-568.

✓ **It is important to practice fluid replacement during training so that it becomes second nature during competition. Drinking during training also helps the gastrointestinal system adapt to consuming increased volumes of fluid and nutrients.**
Consuming beverages during physical activity comes with logistical and gastrointestinal challenges that are amenable to regular practice. For example, drinking enough while running or cycling requires cups, bottles, or backpacks that allow for ease of drinking, along with the ability to resupply or access additional fluids when needed. The stomach and small intestine are also challenged to maintain a rate of absorption of water and solutes (carbohydrates and electrolytes) to match the increased hydration and carbohydrate oxidation needs of intense training and competition. Practicing drinking during training can improve the ability to consume enough fluid to offset sweat loss during exercise and provide ample carbohydrates to fuel active muscles.

- Brouns F, Beckers E. Is the gut an athletic organ? Digestion, absorption and exercise. *Sports Med*. 1993;15(4):242-57.
- Jeukendrup AE. Training the gut for athletes. *Sports Med*. 2017;47(1):101-110.
- Martinez IG, Mika AS, Biesiekierski JR, Costa RJS. The effect of gut-training and feeding-challenge on markers of gastrointestinal status in response to endurance exercise: A systematic literature review. *Sports Med*. 2023;doi:10.1007/s40279-023-01841-0.
- Murray R. Training the gut for competition. *Curr Sports Med Rep*. 2006;5:161-164.

✓ **Wearable devices designed to monitor sweat rates and hydration status hold promise in helping physically active people avoid dehydration, provided the technology can be shown to produce accurate, reliable, and useful feedback.**
Consumers can already choose from a number of commercial products that provide real-time feedback that is transferred from wearable skin patches to smartphone apps. This technology allows users to be notified about the onset and rate of sweating, along with the sodium content of sweat, so that hydration practices can be adjusted accordingly. This technology holds great promise for helping athletes, workers, and soldiers to maintain proper hydration and reduce the risk of heat illness.

- Choi J, Ghafferi R, Baker LB, Rogers JA. Skin-interfaced systems for sweat collection and analytics. *Sci Adv*. 2018;4:1-9.
- Rodin D, Shapiro Y, Pinhasov A, Kreinin A, Kirby M. An accurate wearable hydration sensor: Real-world evaluation of practical use. *PloS one*. 2022;17(8):1-13.
- Uchida K, Ogawa Y, Kataoka Y, et al. New portable device for continuous measurement of sweat rate under heat stress during field tests. *J Appl Physiol*. 2022;132(4):974-983.

✓ **Drinking cool, flavored beverages can encourage the voluntary fluid intake needed to minimize dehydration.**
It should be no surprise that people voluntarily drink more when they enjoy the taste of a beverage. This observation remains true during physical activity. However, taste preferences change between rest and exercise; the beverage characteristics that we most enjoy at rest have less appeal when we are hot and sweaty. A properly formulated sports drink incorporates those differences in flavor intensity, perceived sweetness, aftertaste, mouthfeel, and tartness to taste best when people need it most.

- Appleton KM. Changes in the perceived pleasantness of fluids before and after fluid loss through exercise: a demonstration of the association between perceived pleasantness and physiological usefulness in everyday life. *Physiol Behav*. 2005;83(5):813-9.
- Baker LB, Jeukendrup AE. Optimal composition of fluid-replacement beverages. *Comp Physiol*. 2014;4(2):575-620.
- Horswill CA. Effective fluid replacement. *Int J Sport Nutr*. 1998;8:175-195.
- Passe DH. Physiological and psychological determinants of fluid intake. In: Maughan R, Murray R, eds. *Sports Drinks: Basic Science and Practical Aspects*. CRC Press; 2001:45-88.
- Wilk B, Bar-Or O. Effect of drink flavor and NaCl on voluntary drinking and hydration in boys exercising in the heat. *J Appl Physiol*. 1996;80(4):1112-1117.

✓ **Hyperhydrating before physical activity can be accomplished by consuming beverages containing glycerol or sodium (e.g., sodium chloride, sodium citrate, sodium bicarbonate) in an attempt to expand plasma volume and retain fluid within the body.**
Although hyperhydration does not offer many advantages under normal circumstances of training and competition, there are circumstances in which hyperhydration can be of benefit. For instance, workers, soldiers, and athletes who are faced with high-heat environments with limited opportunities to consume fluid can improve their tolerance to such environments by hyperhydrating beforehand.

- Burke LM, Castell LM, Casa DJ, et al. International Association of Athletics Federations Consensus Statement 2019: Nutrition for Athletics. *Int J Sport Nutr Exerc Metab*. 2019:1-12.
- McDermott BP, Anderson SA, Armstrong LE, et al. National Athletic Trainers' Association Position Statement: Fluid Replacement for the Physically Active. *J Athl Train*. Sep 2017;52(9):877-895.
- Mora-Rodriguez R, Hamouti N. Salt and fluid loading: Effects on blood volume and exercise performance. *Med Sport Sci*. 2013;59:113-119.
- Savoie FA, Dion T, Asselin A, Goulet ED. Sodium-induced hyperhydration decreases urine output and improves fluid balance compared with glycerol- and water-induced hyperhydration. *Appl Physiol Nutr Metab*. 2015;40(1):51-8.
- Sims ST, van Vliet L, Cotter JD, Rehrer NJ. Sodium loading aids fluid balance and reduces physiological strain of trained men exercising in the heat. *Med Sci Sports Exerc*. 2007;39(1):123-30.

✓ **When large sweat losses are expected and when performance in training or competition is important, properly formulated sports drinks can provide benefits that are superior to those of plain water.**
Consuming simple carbohydrates and relatively low levels of electrolytes during vigorous physical activity has repeatedly been shown to improve hydration status and performance compared to ingesting plain water (as a flavored and artificially sweetened placebo). Carbohydrates help stimulate rapid fluid absorption and supply energy to active muscles and brain. Electrolytes (e.g., sodium, potassium, and other minerals) help keep the ingested fluid in the body. In short, the proper amount and types of carbohydrates and electrolytes augment the physiological and metabolic responses to hard exercise that allow for improved performance capacity.

- Baker LB, Jeukendrup AE. Optimal composition of fluid-replacement beverages. *Comp Physiol*. 2014;4(2):575-620.
- Lamb DR, Brodowicz GR. Optimal use of fluids of varying formulations to minimise exercise-induced disturbances in homeostasis. *Sports Med*. 1986;3(4):247-74.
- Williams C, Rollo I. Carbohydrate nutrition and team sport performance. *Sports Med*. 2015;45 (Suppl 1):S13-22.

HYPONATREMIA

✓ **Drinking too much water or other beverages (e.g., beer) can lower the sodium concentration in the blood, causing a dangerous condition known as hyponatremia.**
Hyponatremia has claimed the lives of people both at rest and during/after exercise. A blood sodium concentration less than 135 mmol/L—and particularly less than 130 mmol/L—creates an osmotic impetus that favors the movement of water molecules into the brain. This results in brain swelling, leading to confusion, loss of coordination, seizures, coma, and death. Drinking far in excess of sweat loss will quickly lower blood sodium concentration (normal range is 138 - 142 mmol/L) because we can absorb fluid faster than we can urinate out the excess. This rare condition can also be caused by losing large amounts of sodium in sweat and drinking large volumes of low-sodium beverages.

- Eichner ER. Six paths to hyponatremia. *Curr Sports Med Rep*. 2009;8(6):280-281.
- Hew-Butler T, Loi V, Pani A, Rosner MH. Exercise-associated hyponatremia: 2017 update. *Front Med*. 2017;4:21:1-10.
- Lewis D, Blow A, Tye J, Hew-Butler T. Considering exercise-associated hyponatraemia as a continuum. *BMJ Case Rep*. 2018;1-5.
- Murray B, Eichner ER. Hyponatremia of exercise. *Curr Sports Med Rep*. 2004;3:117-118.

✓ **Consuming sodium during prolonged exercise (e.g., > 2 hours) is important for those who lose large volumes of sweat, in part to reduce the risk of hyponatremia.**
Sodium is a critical electrolyte (mineral; ion) in part because of its role in maintaining the volume of the extracellular space and especially that of blood (plasma) volume. Losing water and sodium in sweat contributes to a progressive fall in blood volume and an eventual decline in blood sodium concentration, a drop that is exacerbated by consuming fluids low in sodium. For that reason, replacing some of the sodium lost in sweat during exercise helps protect blood volume, helps maintain blood sodium concentration, and reduces the risk of hyponatremia.

- Hew-Butler T, Rosner MH, Fowkes-Godek S, et al. Statement of the 3rd International Exercise-Associated Hyponatremia Consensus Development Conference, Carlsbad, California, 2015. *Brit J Sports Med*. 2015;49(22):1432-46.
- Klingert M, Nikolaidis PT, Weiss K, Thuany M, Chlibkova D, Knechtle B. Exercise-associated hyponatremia in marathon runners. *J Clin Med*. 2022;11(22):1-22.
- Montain SJ, Cheuvront SN, Sawka MN. Exercise associated hyponatraemia: quantitative analysis to understand the aetiology. *Brit J Sports Med* 2006;40(2):98-105.

REHYDRATION AFTER PHYSICAL ACTIVITY

✓ **Although it is best to drink enough during physical activity to minimize dehydration, many people will finish their activity at least slightly dehydrated. Rehydrating quickly after physical activity helps speed recovery of physical and mental capacities.**
Dehydration after physical activity is common because many people fail to drink enough to minimize dehydration during exercise. Anytime rapid rehydration is required, doing so speeds recovery and enables a faster return of physical and cognitive capabilities.

- McCartney D, Irwin C, Cox GR, Desbrow B. The effect of different post-exercise beverages with food on ad libitum fluid recovery, nutrient provision, and subsequent athletic performance. *Physiol Behav*. 2018;201:22-30.
- Shirreffs SM, Maughan RJ. Rehydration and recovery of fluid balance after exercise. *Exerc Sport Sci Rev*. 2000;28(1):27-32.
- Shirreffs SM, Armstrong LE, Cheuvront SN. Fluid and electrolyte needs for preparation and recovery from training and competition. *J Sports Sci*. 2004;22(1):57-63.

✓ **Rapid rehydration can be achieved by consuming foods and fluids containing sodium and other electrolytes.**
The complete restoration of body fluid balance after exercise depends upon replacing the water and the electrolytes lost in sweat. Sodium is undeniably the most important electrolyte to replace because it is the mineral lost in the greatest concentration in sweat and it is the primary osmotic impetus for the return of blood volume to normal. Other electrolytes such as potassium, calcium, magnesium, and phosphorus also play an important role in rehydration because they provide an osmotic impetus for return of water molecules to the intracellular fluid space.

- Berry CW, Murray B, Kenney WL. Scientific basis for a milk permeate-based sports drink – A critical review. *Int Dairy J*. 2022;127:1-8.
- Evans GH, James LJ, Shirreffs SM, Maughan RJ. Optimizing the restoration and maintenance of fluid balance after exercise-induced dehydration. *J Appl Physiol*. 2017;122:945-951.
- McCartney D, Irwin C, Cox GR, Desbrow B. The effect of different post-exercise beverages with food on ad libitum fluid recovery, nutrient provision, and subsequent athletic performance. *Physiol Behav*. 2018;201:22-30.

✓ **Complete rehydration usually requires the consumption of a volume of fluid that is greater than the fluid deficit (e.g., drink 1.25-1.50 liters [quarts] for each kilogram [2.2 lb] of weight lost.)**
Although urine production by the kidneys slows during exercise as a way to conserve body fluids, it returns to normal during recovery. The return to normal kidney function, coupled with drinking, increases urine production such that full rehydration can only be achieved when a fluid volume in excess of sweat loss is consumed (to compensate for the obligatory urine production.)

- Maughan RJ, Leiper JB, Shirreffs SM. Restoration of fluid balance after exercise-induced dehydration: effects of food and fluid intake. *Eur J Appl Physiol Occup Physiol*. 1996;73(3-4):317-25.
- Maughan RJ, Shirreffs SM. Recovery from prolonged exercise: restoration of water and electrolyte balance. *J Sports Sci*. 1997;15(3):297-303.
- Shirreffs SM, Taylor AJ, Leiper JB, Maughan RJ. Post-exercise rehydration in man: effects of volume consumed and drink sodium content. *Med Sci Sports Exerc*. 1996;28(10):1260-71.
- Thomas TD, Erdman KA, Burke LM. Nutrition and athletic performance. *Med Sci Sports Exerc*. 2016;48(3):543-568.

✓ **Whenever rapid rehydration is needed (e.g., between tournament games or two-a-day practices), avoid consuming alcoholic drinks because of their diuretic effects.**
Alcohol (ethanol) is a diuretic because it temporarily depresses the level of antidiuretic hormone (ADH; vasopressin) in the bloodstream. As a result, urine production increases. Increased fluid loss via urine production increases the time required for complete rehydration, particularly when the time to fully rehydrate is short. Alcohol consumption appears to be less problematic when there is 24 hours or more available to rehydrate and when beer containing less than 5% ABV is consumed. Binge drinking of large volumes of alcohol is always problematic for hydration status. Furthermore, alcohol is a central nervous system depressant and will impair physical and cognitive performance.

- Flores-Salamanca R, Aragon-Vargas LF. Postexercise rehydration with beer impairs fluid retention, reaction time, and balance. *Appl Physiol Nutr Metab*. 2014;39(10):1175-1181.
- Shirreffs, SM, Maughan RJ. Restoration of fluid balance after exercise-induced dehydration: effects of alcohol consumption. *J Appl Physiol*. 1997;83(4):1152-1158.
- Wijnen AH, Steennis J, Catoire M, Wardenaar FC, Mensink M. Post-exercise rehydration: Effect of consumption of beer with varying alcohol content on fluid balance after mild dehydration. *Front Nutr*. 2016;3(45):1-8.
- Wynne JL, Wilson PB. Got Beer? A Systematic Review of Beer and Exercise. *Int J Sport Nutr Exerc Metab*. 2021;31(5):438-450.

✓ **Sports drinks containing ingredients such as amino acids and additional electrolytes may provide hydration advantages compared to water and traditional sports drinks.**
Emerging research shows that ingesting a blend of selected amino acids or the electrolyte profile found in cow's milk can enhance the hydration characteristics of sports drinks. This improvement is thought to be due to the distribution of amino acids and electrolytes in both intracellular and extracellular fluid compartments.

- Berry CW, Wolf ST, Murray B, Kenney WL. Hydration efficacy of a milk permeate-based oral hydration solution. *Nutrients*. 2020;12(5):1-16.
- Berry CW, Murray B, Kenney WL. Scientific basis for a milk permeate-based sports drink – A critical review. *Int Dairy J*. 2022;127:1-8.
- Clarke MM, Stanhewicz AE, Wolf ST, Cheuvront SN, Kenefick RW, Kenney WL. A randomized trial to assess beverage hydration index in healthy older adults. *Amer J Clin Nutr*. 2019;109(6):1640-1647.
- Wolf ST, Stanhewicz AE, Clarke MM, Cheuvront SN, Kenefick RW, Kenney WL. Age-related differences in water and sodium handling after commercial hydration beverage ingestion. *J Appl Physiol (1985)*. 2019;126(4):1042-1048.

✓ **Most caffeinated beverages do not contain enough caffeine to impede rehydration after exercise or during the day, especially when consumed with foods containing sodium and other electrolytes.**
Caffeine has a mild diuretic effect in caffeine-naive or caffeine-starved people. Those who ingest caffeine on a regular basis are less likely to experience caffeine-induced diuresis. Also, it is unusual for people to consume large amounts of caffeine without also consuming food, which offsets the diuretic impact of caffeine. Exceptions to this generalization include ingesting multiple energy drinks or energy shots in the absence of food intake. Research indicates that when caffeine consumption is less than 250 - 300 mg/day, the diuretic impact of caffeine is negligible.

- Grandjean AC, Reimers Kj, Bannick KE, Haven MC. The effect of caffeinated, non-caffeinated, caloric and non-caloric beverages on hydration. *J Am Coll Nutr*. 2000;19(5):591-600.
- Killer SC, Blannin AK, Jeukendrup AE. No evidence of dehydration with moderate daily coffee intake: a counterbalanced cross-over study in a free-living population. *PloS ONE*. 2014;9(1):1-8.
- Seal AD, Bardis CN, Gavrieli A, et al. Coffee with high but not low caffeine content augments fluid and electrolyte excretion at rest. *Front Nutr*. 2017;4(40):1-6.

Listed below are verbatim recommendations from three recent position stands on fluid replacement and physical activity. All of these statements were considered in creating the general recommendations above.

IAAF 2019

- What is irrefutable is that the fluid needs of most Athletes are determined by their reliance on the evaporation of sweat to dissipate the heat produced during exercise or absorbed from a hot environment.
- It may be possible and useful to drink to the dictates of thirst when sweat losses are low and the opportunities to drink are plentiful. However, other circumstances require a proactive plan, that is, when performance is affected by hypohydration and the likelihood of large losses is matched with fewer opportunities for hydration.
- Aim to keep net fluid deficit <2-3%, especially in hot weather.
- Consider pre-race hyperhydration if large fluid deficit is anticipated.
- Do not over-drink by consuming fluid in excess of sweat losses. A good tip is to avoid drinking beyond thirst cessation if not aware of individual fluid needs.

ACSM 2016

- Although there is complexity and individuality in the response to dehydration, fluid deficits of >2% body weight can compromise cognitive function and aerobic exercise performances, particularly in hot weather.
- Decrements in the performance of anaerobic or high- intensity activities, sport-specific technical skills, and aerobic exercise in a cool environment are more commonly seen when 3%–5% of BW is lost due to dehydration.
- Assuming an athlete is in energy balance, daily hydration status may be estimated by tracking early morning body weight (measured upon waking and after voiding) since acute changes in body weight generally reflect shifts in body water.
- Urinary specific gravity and urine osmolality can also be used to approximate hydration status by measuring the concentration of the solutes in urine. When assessed from a midstream collection of the first morning urine sample, a urinary specific gravity of < 1.020, perhaps ranging to < 1.025 to account for individual variability, is generally indicative of euhydration.
- Urinary osmolality reflects hypohydration when >900 mOsmol/kg, while euhydration is considered as <700 mOsmol/kg.
- Athletes may achieve euhydration prior to exercise by consuming a fluid volume equivalent to 5–10 ml/kg BW (~2–4 ml/lb) in the 2 to 4 hours before exercise to achieve urine that is pale yellow in color while allowing for sufficient time for excess fluid to be voided.
- Sodium consumed in pre-exercise fluids and foods may help with fluid retention.
- Ideally, athletes should drink sufficient fluids during exercise to replace sweat losses such that the total body fluid deficit is limited to < 2% BW.
- Routine measurement of pre- and post-exercise BW, accounting for urinary losses and drink volume, can help the athlete estimate sweat losses during sporting activities to customize their fluid replacement strategies.
- The fluid plan that suits most athletes and athletic events will typically achieve an intake of 0.4 to 0.8 L/h, although this needs to be customized to the athlete's tolerance and experience, their opportunities for drinking fluids and the benefits of consuming other nutrients (eg, carbohydrate) in drink form.
- Ingestion of cold beverages (0.5 °C) may help reduce core temperature and thus improve performance in the heat. The presence of flavor in a beverage may increase palatability and voluntary fluid intake.
- Over-drinking fluids in excess of sweat and urinary losses is the primary cause of hyponatremia (blood sodium < 135 mmol/L), also known as water intoxication, although this can be exacerbated in cases where there are excessive losses of sodium in sweat and fluid replacement involving low-sodium beverages.
- Sodium should be ingested during exercise when large sweat sodium losses occur. Scenarios include athletes with high sweat rates (>1.2 L/h), ''salty sweat,'' or prolonged exercise exceeding 2 hours in duration.
- Thirst sensation is often dictated by changes in plasma osmolality and is usually a good indication of the need to drink but not that the athlete is dehydrated.

- Older athletes may present with age-related decreases in thirst sensation and may need encouragement to drink during and post-exercise.
- Most athletes finish exercising with a fluid deficit and may need to restore euhydration during the recovery period.
- Rehydration strategies should primarily involve the consumption of water and sodium at a modest rate that minimizes diuresis/urinary losses.
- The presence of dietary sodium/sodium chloride (from foods or fluids) helps to retain ingested fluids, especially extracellular fluids, including plasma volume. Therefore, athletes should not be advised to restrict sodium in their post-exercise nutrition particularly when large sodium losses have been incurred.
- [E]ffective rehydration requires the intake of a greater volume of fluid (eg, 125%–150%) than the final fluid deficit (eg, 1.25–1.5 L fluid for every 1 kg BW lost).
- Excessive intake of alcohol in the recovery period is discouraged due to its diuretic effects.
- However, the previous warnings about caffeine as a diuretic appear to be overstated when it is habitually consumed in moderate (e.g. < 180 mg) amounts.

NATA 2017

- Among individuals in free-living conditions, habitual fluid intake and urine production are highly variable. Furthermore, sweat rate, thirst, and fluid intake during exercise vary greatly. Therefore, individualized fluid-maintenance recommendations need to be considered for physically active people.
- Both severe clinical hypohydration and hyperhydration can degrade athletic performance and are potentially fatal.
- Optimal hydration is a modifiable factor that should be attempted to help prevent the onset of heat illness.
- 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.
- 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.
- 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.
- Physically active individuals should maintain euhydration (+1% to –1%) for optimal exercise performance.
- Heat acclimatization should be a factor in developing individualized fluid-replacement plans.
- Water or other palatable fluids should be easily accessible before, during, and after activity.
- Athletes often prefer cool, flavored beverages; these should be available, when possible, to promote rehydration.
- 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.
- Pre-exercise sodium ingestion can expand vascular fluid volumes. Ingesting sodium during activity delays blood sodium decreases in some people but has a limited preventive effect in others.
- Sodium supplementation before and during exercise should be individualized based on specific losses and needs and should be practiced.
- Beverages with <4% alcohol content do not dehydrate active people. However, beverages with greater alcohol content facilitate excessive diuresis and should be discouraged for fluid replacement.
- 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. This measure is valid only when compared with at least 3 consecutive days of euhydrated baseline average mass. 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.

- 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.
- Whole-body sweat losses in children are less than in adults, and children require different rehydration plans than adults.
- Beyond age 50 years, a person's thirst sensitivity decreases with hypohydration and urine-concentrating ability decreases. Extra consideration for hydration should be directed toward these populations during physical activity.
- 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.
- 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.
- 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.
- During exercise, the goal for the physically active is to maintain hydration and not allow more than a 2% body mass loss.
- [E]very individual should know his or her personal sweat rate and develop a hydration strategy based on individual needs.
- 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).
- 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.
- Endurance athletes may be aided by fluids containing carbohydrates and electrolytes during extended training bouts and competitions. 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.
- Caffeine does not compromise rehydration or increase urine output when consumed in small quantities (up to 3 mg/kg) during or after exercise. Small amounts of caffeine in a rehydration beverage should not cause harm to the physically active postexercise.