KEY POINTS

* The 2004 recommendations on water and sodium intake from the Institute of Medicine (IOM) of the National Academy of Sciences are targeted primarily at sedentary Americans. These guidelines for water and salt intake should not be applied to athletes.
* Athletes who follow the IOM recommendations to the letter may actually put themselves at risk for unintended decreases in performance or even untoward health consequences.
* Daily fluid needs for athletes are often large, and relying solely on thirst to stay well hydrated will lead to persistent hypohydration.
* The volume of fluid consumed by athletes during and especially after exercise should be based on the volume of fluid lost in sweat. The recommended fluid intake can be estimated as the difference between the athlete's body weight before and after activity.
* The range of individual sweat sodium losses during exercise is extremely large. Unless sodium restriction has been recommended for a particular athlete for health reasons, athletes should liberally salt their food and consume sports drinks that provide needed sodium and other electrolytes.

INTRODUCTION

In early 2004, the Institute of Medicine's (IOM) Food and Nutrition Board released its recommendations on Dietary Reference Intakes (DRI) for water, potassium, sodium, chloride, and sulfate. To accomplish this formidable task, the IOM convened a ten-member expert panel that was chaired by Lawrence J. Appel, M.D., M.P.H., Professor of Medicine, Epidemiology, and International Health at Johns Hopkins University. The panel of scientists from the U.S. and Canada was charged with determining, where possible, appropriate dietary intake levels for water, salt, and potassium necessary to maintain health and reduce chronic disease risk.

The 500-page report reviewed available research data and provided some important information about the hydration status and hydration needs of the average sedentary adult. Relying on phrases such as "the vast majority of healthy people" and "on a daily basis," the report provides guidelines for how much fluid we should consume, reviews the factors that govern fluid intake, and provides recommendations for daily water, sodium, and potassium consumption. However, for the athlete or fitness enthusiast, some of these recommendations may not be appropriate, and—taken to an extreme—may be harmful. It is important that
the team physician, athletic trainer, sports nutritionist, and other sports health professionals correctly interpret this information.

Making Sense of the DRIs

Dietary guidelines for Americans and Canadians are established by expert committees functioning under the Food and Nutrition Board of the Institute of Medicine, one of the institutes of the National Academy of Sciences. In the past, the dietary guidelines have been published in one text, titled *Recommended Dietary Allowances* (National Research Council, 1989). In recent years, updated texts on Dietary Reference Intakes have been published for specific groups of nutrients. For example, one such DRI text is devoted to vitamins C and E, the mineral selenium, and the carotenoids (Institute of Medicine, 2000).

The DRIs are a set of dietary guidelines comprising:

* **EAR**—*Estimated Average Requirement*—The average daily nutrient intake estimated to meet the requirements of 50% of people in a particular lifestage and gender group. For example, the EAR for vitamin C is 75 mg for men, ages 19-30 (and 60 mg for women).

* **RDA**—*Recommended Dietary Allowances*—RDAs are established when there is enough science to confidently identify the intake of a particular nutrient that is sufficient to meet the nutritional requirements of 97-98% of people in a certain lifestage and gender category. For example, the RDA for vitamin C for women ages 19-30 is 75 mg/day. That doesn't mean that 75 mg of vitamin C must be ingested every day. Some days may be less, other days more, but the average should be 75 mg/day.

* **AI**—*Adequate Intake*—When an RDA cannot be determined, the AI serves as an estimate of the daily nutrient intake that is assumed to be adequate. This implies that there is a low probability of inadequacy at the AI level of intake for a particular lifestage and gender group. For example, the AI for calcium for females and males between the ages of 9 and 18 is 1,300 mg/day.

* **UL**—*Tolerable Upper Limit*—The highest average daily intake that likely poses no risk of adverse effects for most individuals. For example, the UL for vitamin C for adults over age 19 is 2,000 mg/day. If the UL is consistently exceeded, problems are not certain to occur, just more likely.

In establishing the water and electrolyte requirements, the expert panel reviewed all of the related scientific literature and closely evaluated the quality of each study to determine the overall usefulness of the data. Based upon that review, the panel made recommendations for daily water, sodium, chloride, potassium, and sulfate intakes.

Meeting Daily Water Needs

The challenge of accurately and clearly identifying population-wide guidelines for nutrient intake is evident in this statement from the DRI report: "on a day to day basis, fluid intake, driven by thirst and the consumption of beverages at meals, allows maintenance of hydration status and total body water at normal levels" (Institute of Medicine, 2004, p. S-5). This seemingly simple statement is at once correct, incorrect, and somewhat misleading. The correct part of the statement is that, on a daily basis, most healthy adults do consume enough water from drinking a variety of beverages (providing about 80% of daily water needs) and eating food (providing the remaining 20%) to maintain health and proper physiological function.

The incorrect portion of the statement is that thirst determines how much we drink day in and day out. Actually, it is largely behavior and not thirst that dictates daily fluid intake (Phillips et al., 1984). We drink when we eat, we drink when we pass a water fountain or the kitchen refrigerator, and we drink when cold, palatable fluids are readily available, such as at social gatherings, parties, or meetings. Thirst has very little
to do with this sort of daily fluid-in, fluid-out calculation at all. We become thirsty when our bodies sense either a decrease in body water (sensed as a low blood volume) or, more often, an increase in sodium concentration (primarily sensed by cells of the brain). Therefore, we experience the sensation of thirst only when our bodies are stressed by fairly significant fluid losses or changes in sodium status (both of which can be altered by fluid deprivation, prolonged sweating, diuresis, diarrhea, and vomiting). Even when we do experience thirst, the sensation is not well correlated with the body's fluid needs (Hubbard et al., 1984). Both the American College of Sports Medicine (ACSM) and the National Athletic Trainers' Association (NATA) issued press releases soon after the IOM report, cautioning physically active people against "letting their thirst guide them." Rather, the clear and important health message should be that thirst alone is not the best indicator of dehydration or the body's need for fluid, a fact that is particularly true during exercise.

The misleading part of the statement, or at least one that lends itself to misinterpretation, is exactly what "on a daily basis" really means. The summary section of the IOM report does state that, "Given the extreme variability in water needs which are not solely based on differences in metabolism, but also on environmental conditions and activity, there is not a single level of water intake that would ensure adequate hydration and optimal health for half of all apparently healthy persons in all environmental conditions" (Institute of Medicine, 2004, p. S-4). (For that reason, an EAR for water could not be established.) However, both ACSM and NATA feel strongly that such a caveat does not go far enough to convince the active adult population that ingesting fluids before, during, and after exercise, sport, physical work, or other occasions of increased activity is an important part of regulating body temperature and maintaining cardiovascular function.

Dehydration resulting from the failure to adequately replace fluids during exercise can lead to impaired heat dissipation, which can elevate body core temperature and increase strain on the cardiovascular system (Montain & Coyle, 1992; Nadel et al., 1979). Dehydration is a potential threat to all athletes and recreational exercisers, especially those who are not acclimatized for strenuous activity in hot environments. To minimize the potential for heat exhaustion and other forms of heat illness, ACSM and NATA experts recommend that water losses due to sweating during exercise be replaced at a rate close to or equal to the sweat rate (American College of Sports Medicine, 1996; National Athletic Trainers Association, 2000). This is best -and most easily -accomplished by having athletes weigh themselves before and after an exercise bout. Weight loss indicates the presence of dehydration and the need to increase fluid intake during future exercise bouts. Weight gain is a signal to drink less.

Relying on thirst is especially bad advice for older exercisers. As we age, thirst becomes an even poorer indicator of the body's fluid needs. Specifically, older exercisers experience a weaker sensation of thirst in response to losses of blood volume that accompany dehydration (Kenney & Chiu, 2001). For a given level of dehydration, the elderly exhibit both a reduced thirst sensation and a reduced fluid intake.

IOM Recommendations for Daily Water Intake

Because EAR and RDA values could not be established for daily water intake due to the large variation in water needs across the population, the IOM panel established AI values of 3.7 L/day in males (130 oz; the equivalent of 16 cups of fluid) and 2.7 L/day for females (95 oz; about 12 cups). These values represent an improvement of sorts from the 1989 RDA recommendations (National Research Council, 1989); in the 1989 report, daily water intake for adults was recommended to range between 1.0 and 1.5 ml water/kcal energy expenditure. In other words, a person expending 2,000 kcal per day would require 2 liters of water, whereas someone expending 6,000 kcal/day would require 6 liters of water. This rule of thumb remains one way to estimate daily water needs, but the 2004 recommendations are considerably more user-friendly.

For physically active people, daily fluid needs often exceed 3-4 liters per day and can sometimes be in excess of 10 liters per day (Institute of Medicine, 2004, p. 4-51). When body water loss is great (as is typically the case when sweating for more than two hours per day), keeping track of hydration status
becomes important. Laboratory methods are available to assess indicators of hydration (e.g., plasma osmolality, urine specific gravity, deuterium oxide dilution), but athletes can rely on a simple, practical approach. Athletes engaged in vigorous training accompanied by profuse sweating should record body weights after urinating each morning and monitor the color of the urine. If body weight has dropped by more than 1 pound (about 0.5 kg) from the day before and if urine color is more like apple juice than lemonade, dehydration is likely (Institute of Medicine, 2004, p. 4-24, 4-26) and the athlete should pay extra attention to fluid intake during the day.

The IOM report also addresses the use of alcoholic and caffeinated beverages. "While consumption of beverages containing caffeine and alcohol have been shown in some studies to have diuretic effects, available information indicates that this may be transient in nature, and that such beverages can contribute to total water intake and thus can be used in meeting recommendations for dietary intake of total water" (Institute of Medicine, 2004, p. S-5). What does this mean for the athlete? In brief, it means that the periodic ingestion of beverages containing caffeine and alcohol probably will not compromise hydration status. However, common sense dictates that such drinks should not be ingested at times when the effects of caffeine and alcohol on stimulating excess water loss in the urine could compromise hydration status. Thus, beverages containing caffeine or alcohol should be avoided before or after heavy training, when maintaining and restoring hydration status is important.

The IOM report also makes mention of the potential danger of excessive fluid consumption which may, in the extreme, result in a low blood sodium concentration or hyponatremia (Murray et al., 2003). While hyponatremia is a rare occurrence, it is a dangerous condition that may arise when athletes drink too much water, diluting the body's sodium. It is most often seen in endurance exercise, such as in marathons and triathlons. Because exertional hyponatremia is such a rare occurrence and because healthy people have the ability to excrete excess water, the IOM panel did not set a UL for daily water consumption.

Water and sports drinks are not dangerous to athletes when consumed as recommended -in volumes approximating sweat losses. However, water quenches the sensation of thirst before body fluid replacement is achieved, so thirst should not be the only determinant of how much fluid is consumed under such conditions. Consuming a sports drink with adequate sodium (at least 100 mg/8 oz) encourages continued drinking, more adequately replacing the active individual's fluid and electrolyte needs.

**Meeting Daily Sodium Needs**

As is the case with daily water needs, daily sodium needs can also vary widely, especially for athletes, workers, and soldiers -in other words, anyone who sweats profusely. For sedentary individuals, the primary route of sodium loss is via the urine. The kidneys can either conserve sodium if sodium intake falls below needs or can excrete sodium whenever intake exceeds needs. The latter scenario is virtually always the case with sedentary people. For example, it is estimated that the average American consumes somewhere between 8 and 12 g of table salt per day. (Table salt—sodium chloride—is 40% sodium, so there are 3.2-4.8 g sodium in 8-12 g of salt). This amount of sodium intake is about 20 to 30 times the amount of sodium needed to replace obligatory losses from urine (~ 25 mg/day), skin (~100 mg /day), and feces (~25 mg /day). The IOM report points out the association across the entire population between increased sodium intake and elevated blood pressure, and this relationship forms the basis for the stringent recommendation made by the IOM panel regarding daily sodium intake that will be described later. Research indicates that reduced consumption of salt, coupled with increased potassium intake, can blunt the age-related rise in blood pressure.

In a similar vein to recommendations for fluid intake, the IOM's guidance on daily sodium intake should not be applied to most athletes. Athletes should be encouraged to liberally salt their food and consume sports drinks when acclimatizing to, or exercising in, hot conditions. While cutting back on overall sodium in the diet may be sound advice for the sedentary public, athletes have a special need to replenish lost sodium
stores. Drastically reducing sodium intake is the last thing a football player beginning two-a-day practices in August should do.

Athletes need more sodium because they lose more sodium in sweat. The range of sodium lost in the sweat of athletes is large because some athletes are salty sweaters and others are not. Sweat is saltier during the early stages of training and heat acclimation than after an athlete is fit and fully acclimated to exercise in the heat. Here are three examples of just how large daily sodium loses can be in athletes.

* Kris is a triathlete who typically trains for 2 hours each weekday and for at least 4 hours on either Saturday or Sunday. Kris is very fit and well acclimated to the heat. On average she loses 1.5 liters of sweat per hour of training. Being fit and acclimated, her sweat sodium concentration is low, 30 mmol (690 mg)/liter. Each weekday, she loses 3 liters of sweat and 2,000 mg of sodium (5 g of salt; about one teaspoon). During her weekend workout she loses at least 4,000 mg of sodium (10 g of salt). Provided she liberally salts her food and consumes a sports drink with adequate sodium rather than water during her workouts, she will likely meet her daily sodium needs.

* Damien is a middle linebacker beginning two-a-day practices in August. Although he works out regularly during the summer, he relies on summer training camp to top off his conditioning for the season. His fitness is above average, but he isn't fully acclimated to the heat. He trains for 3.5 hours each day and typically loses about 6 liters of sweat. His sweat sodium concentration is "average"at 50 mmol (1150 mg)/liter. Each day, Damien will lose 6,900 mg of sodium (over 17 g of salt). Damien's need for salt intake is obviously very high, but can be supplied by the diet if he salts his meals and consumes low-fat, salty foods (e.g., pretzels, tomato juice, chicken noodle soup)

* Carrie is a fitness enthusiast who works out for an hour each day, either jogging or kickboxing. She loses a liter of sweat with each workout, and her sweat contains 40 mmol (920 mg) of sodium per liter. With each workout, Carrie loses only 920 mg of sodium (2.3 g of salt). Her sodium needs can easily be met by her diet. As she increases her fitness and acclimation, her sweat sodium concentration will decrease, but her sweat rate will increase, so her need for dietary sodium may not change.

Of these three examples, the 2004 IOM recommendations for sodium intake would meet only Carrie's needs. IOM Recommendations for Daily Sodium and Chloride Intake The IOM report sets the AI for salt at 3.8 g/day (1.5 g of sodium and 2.3 g of chloride) "to cover [sweat sodium] loses in unacclimatized individuals who are exposed to high temperatures or who become physically active " (Institute of Medicine, 2004, p. 6-1). The IOM report recognizes that physically active people have an increased need for salt: "This AI does not apply to highly active individuals who lose large amounts of sweat on a daily basis"(Institute of Medicine, 2004, p. 6-1). Furthermore, a UL level of 5.8 g of salt (2.3 g of sodium) per day is suggested.

The practical message from the IOM report is clear: sedentary individuals have a low requirement for dietary salt, whereas physically active people may require dietary salt intake well in excess of both the recommended AI and the UL.

Meeting Daily Potassium and Sulfate Needs

Adequate potassium intake is important in lowering blood pressure, blunting the adverse blood-pressure effects of salt intake, reducing the risk of kidney stones, and potentially reducing bone loss (Institute of Medicine, 2004, p. S-7). Potassium from fruit and vegetable sources was noted to be desired because the potassium is usually bound to citrate. Citrate acts as a buffer and helps protect bone from acid-induced demineralization (thereby also protecting against the formation of kidney stones).

Sweat potassium concentration seldom exceeds 10 mmol (390 mg)/liter. Even at this value, the total potassium losses for the examples provided by Kris, Damien, and Carrie would be 1,200 mg for Kris (in 3
liters of sweat), 2,400 mg for Damien (in 6 liters of sweat), and 390 mg for Carrie (in one liter of sweat), all of which fall below the recommended AI for potassium (see below). Most potassium in the body is intracellular, and the total body potassium content is quite large, so sweat potassium represents only a relatively small percentage of the available potassium. However, there is no doubt that sweating increases the dietary requirement for potassium. For that reason, athletes should be encouraged to consume fruits, vegetables, and juices high in potassium.

Dietary sulfate requirements are easily met by consuming sulfur-containing amino acids. Unlike the case with sodium and chloride, sweat contains little sulfate and does not constitute a meaningful avenue of sulfate loss. There are hundreds of sulfur-containing compounds in the body, and adequate sulfate intake from protein foods, water, and beverages is required to replace the small amount lost in urine and feces.

**IOM Recommendations for Daily Potassium and Sulfate Intake**

The IOM panel recommended an AI of 4.7 g/day for potassium because neither an EAR nor RDA could be established. In the US and Canada, typical potassium intakes are less than the recommended AI, so educational efforts to help boost potassium intake are needed to help increase potassium intake.

Because the typical American and Canadian diet contains adequate-to-excessive amounts of protein, there was no need to set an EAR, RDA, or AI for sulfate. Nor were UL's established for either potassium or sulfate. The recommendations recognize that problems can arise from ingestion of high levels of potassium supplements, but food sources present little risk (Institute of Medicine, 2004, p. S-12).

**SUMMARY**

The 2004 IOM recommendations represent a needed and useful refinement of the water and electrolyte guidelines for Americans and Canadians. But, as clearly stated in the IOM report, the guidelines for water and sodium chloride do not apply to athletes (see supplement accompanying this article). Optimal hydration requires the replacement of water and electrolytes based on individual needs. Physically active people who lose more than 2 liters of sweat in a day should take steps to assure that they are ingesting adequate amounts of water and salt.

**REFERENCES**


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