Hyponatremia of exercise

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Introduction

Exercise-related hyponatremia, unheard of two decades ago, has apparently increased in the past decade and has claimed the lives of athletes, hikers, and soldiers. Low plasma sodium concentration, and therefore low plasma osmolality, disrupts the osmotic balance across the blood-brain barrier, resulting in rapid influx of water into the brain. This causes cerebral edema and a potential cascade of pathophysiology that can be fatal.

The Danger of Hyponatremia

The lower the plasma sodium concentration falls, the faster it drops, and the longer it remains low, the greater the risk of grave complications and death. Normal plasma sodium is 135 to 145 mmol/L. Although it is impossible to give precise figures in clinical medicine, in general, the risk of death is greatest when plasma sodium drops quickly to well below 120 mmol/L. Yet some athletes have survived levels as low as 112 mmol/L, whereas others have died at levels (first measured in the hospital) just over 120 mmol/L. A decrease in plasma sodium to 125 to 134 mmol/L is often benign, with either no symptoms or mild headache and bloating or nausea. However, even mild hyponatremia should be monitored until plasma sodium concentration returns to normal.

With plasma sodium below 125 mmol/L and falling, the symptoms become increasingly severe and can include throbbing headache, vomiting, swollen hands and feet, restlessness, unusual fatigue, wheezy breathing (pulmonary edema), confusion, and disorientation. When sodium drops below 120 mmol/L, seizure, coma, brainstem herniation, respiratory arrest, and death become more likely.

What Causes Hyponatremia of Exercise?

In simple terms, hyponatremia results from an inappropriate increase in total body water (TBW) often accompanied by a reduction in whole body sodium content. TBW can be increased by excessive fluid intake, perhaps augmented by dysfunction of homeostatic systems (especially vasopressin or the renin-angiotensin-aldosterone system), or by a reduction in renal free water clearance. Reduced body sodium content can occur from heavy sweating or inadequate sodium intake.

In athletes and nonathletes alike, hyponatremia can occur in various ways:

1. From excessive water intake alone, as has occurred in people drinking large volumes of water to void for drug tests or to be weighed in follow-up for anorexia nervosa; in children forced to drink water as punishment; and in college students compelled to drink large volumes of water or beer in fraternity hazing. This form of hyponatremia—*hypervolemic hyponatremia*—seems to be the most common form and also may be the main cause of the serious or lethal hyponatremia seen in some women marathon runners. In general, the shorter the athletic event, the more likely that hyponatremia stems from overdrinking before, during, and after the event.
2. From excessive drinking and large sweat sodium loss, as has occurred during endurance athletic events and military exercises. This form of hyponatremia can occur even in the absence of overdrinking, when drinking matches sweat loss, and seems more likely in very long events and in those who for genetic or other reasons have very salty sweat. It may also be a cause of the fatal hyponatremia in girls who take ecstasy at raves and quaff water to avoid overheating as they dance and sweat for hours.
3. In dehydrated endurance athletes, from large sweat sodium losses and ingestion of low-sodium beverages. This form of hyponatremia occurs despite under-drinking, not matching sweat rate. An athlete who loses 10 L of salty sweat and drinks 8 L of water will be both volume depleted (dehydrated) and hyponatremic. Hypovolemic hyponatremia is not the most common form of hyponatremia, but does occur in prolonged endurance events in tropical climes, such as some Ironman-distance triathlons.

The kidneys' limited capacity to excrete excess water quickly can increase the risk of hyponatremia. Maximal urine production is usually less than 1 L per hour, but most adults can drink 2 L of fluid or more per hour. Researchers have shown that plasma sodium levels can plummet when resting subjects over-drink water. The volumes of water ingested in these studies (~ 1.5 qt/h over 2–3 hours) could easily be consumed by an overzealous drinker. During exercise, it is easier for excessive drinking to overwhelm the capacity of the kidneys to excrete excess water because urine production normally declines 20% to 60% from resting values due to a decrease in kidney blood flow. This response helps conserve vital water, yet increases the risk that excessive drinking will lead to hyponatremia.

Who Is at Risk?

Published cases of hyponatremia reflect a preponderance of female victims, an observation that implies that girls and women are somehow more susceptible to hyponatremia. This trend, however, may be more behavioral than biologic. Anecdotal evidence suggests that women are more vigilant drinkers (witness the propensity for women to carry bottled water throughout the day), and female athletes may be more likely to heed, and sometimes exceed, advice from coaches and experts. Some women marathoners and triathletes also over-drink before a race; for example, one woman drank 10 L of fluid the night before the Houston marathon and ended the race with sodium 118 mmol/L.

It also takes less fluid to dilute plasma sodium in women than men, because by nature, women have more body fat and so less TBW than men. Also, hospital studies (not in athletes) suggest that the clinical outcome of hyponatremia is more grave in women than men.

In contrast to petite women, large muscular men are at less risk of hyponatremia simply because it takes a lot of excess fluid to dilute a large extracellular fluid (ECF) compartment. However, large athletes are not immune, because some football players have been hospitalized for hyponatremia. Excessive drinking in any size athlete will dilute the ECF, especially when plain water is the primary fluid. Regardless of body size, athletes who are already hyponatremic from excessive drinking in the days or hours before an event are at greater risk of developing severe exertional hyponatremia, because less fluid is required to drop plasma sodium to dangerous levels.

Some athletes may be at greater risk of hyponatremia because they carry a recessive gene for cystic fibrosis. Cystic fibrosis is most prevalent in people of northern and central European heritage, where one in 20 may carry a recessive gene. Carriers can excrete salty sweat, increasing their risk of severe muscle cramping and hyponatremia. More research is needed to determine the prevalence of this gene among athletes who develop hyponatremia.

How Can Hyponatremia Be Prevented?

Educating athletes about the dangers of excessive drinking and the need to ingest adequate sodium in their diets and during training and competition can help prevent hyponatremia. The goal of drinking during exercise is to minimize body weight loss and therefore reduce the likelihood that dehydration will impair performance and increase the risk of heat illness. A sure sign of drinking too much is weight gain during exercise. If an athlete weighs more after practice than before, that means too much fluid was ingested and the athlete should cut back. During workouts and competitions, athletes should favor sodium-containing sports drinks over water to assure an additional intake of sodium to help stabilize the sodium content of the ECF.

How Should Hyponatremia Be Treated?

Hospital treatment of hyponatremia is not within the scope of this article. But for hyponatremia in the medical tent, one can propose three groups of athletes. If plasma sodium is low and the athlete is clinically hypovolemic (as in some triathletes in tropical climes), one can safely begin with intravenous normal saline, close clinical observation, and monitoring plasma sodium. In this setting, this treatment often suffices. Similarly, if sodium is low but the athlete is clinically overhydrated (hypervolemic), has few symptoms, and is clinically stable, one can safely let the athlete rest under observation in the tent and in time urinate off the excess fluid. But athletes with sodium under 120 or 125 mmol/L (and/or who are clinically ill), perhaps with early pulmonary edema or seizures or obtundation or coma, should go straight to the hospital for likely intensive care and treatment with hypertonic saline.

Conclusions

There is little doubt that proper hydration benefits physiologic function, performance, and health. There is also little doubt that excessive drinking can create a potentially life-threatening situation. It appears that excessive fluid intake is the primary cause in most cases of hyponatremia in athletes. Hyponatremia can be prevented by educating athletes about proper hydration practices and adequate sodium intake.

Recommended Reading

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