The Basics of Proper Hydration During Prolonged Exercise

Martin D. Hoffman, MD

Proper hydration during prolonged exercise can help you avoid performance impairment from dehydration and serious, potentially life-threatening complications from overhydration. In this short summary, I will review some basic principles that should help you maintain proper hydration during an ultramarathon.

1. Expect some weight loss during exercise

The oxidation of stored fuel during exercise results in loss of body weight. Furthermore, production of metabolic water during fuel oxidation and the release of water stored with glycogen as muscle and liver glycogen are metabolized will help to maintain the body's total water pool during exercise. That is because this water that is generated and released within the cell will enter the circulation due to osmotic, hydrostatic and oncotic gradients. Therefore, body weight must be lost during prolonged exercise in order to avoid becoming overhydrated. We have calculated that weight loss during a 100-mile mountain ultramarathon should be on the order of ~3-8 pounds (~2-5% of body weight).[7] The appropriate amount of weight loss should be as much as ~2-6 pounds (~1-4% of body weight) for a 50-mile ultramarathon, and as much as ~5-10 pounds (~3-7% of body weight) for a 200-mile ultramarathon! So, don't be concerned about some weight loss within these ranges. On the other hand, if you are not losing weight or you are gaining weight during exercise, then you should reduce your fluid intake in order to reduce your risk of developing exercise-associated hyponatremia (EAH).

2. Overhydration is a risk for hyponatremia

The primary underlying etiological factor for symptomatic EAH is sustained fluid (water or sports drinks) intake in volumes resulting in the accrual of a positive fluid balance.[6] For most athlete-related symptomatic cases of EAH, impaired water clearance due to non-osmotic secretion of arginine vasopressin is an important contributing factor.[6] While EAH is frequently documented in association with hypovolemia,[8,18] symptomatic EAH is virtually exclusively seen in those who gain or lose inadequate weight during exercise as a result of overhydration.[14,18] Thus, there is no debate that overhydration is a risk for the development of symptomatic EAH. Since there has been considerable morbidity from EAH and a number of deaths have resulted from EAH, avoidance of overhydration is paramount to safe exercise.

3. Drink to thirst

Thirst is an evolutionarily developed and precisely regulated mechanism that protects plasma osmolality and circulating blood volume. These mechanisms prompt when drinking is required to prevent excessive dehydration. Though the concept that thirst provides an adequate stimulus to maintain proper hydration during exercise may still be under debate by some and you have undoubtedly heard that it is inadequate, past recommendations emphasizing that thirst is an inadequate stimulus for maintaining proper hydration were largely intended for situations where dehydration might develop quickly from high sweat rates. There is now ample evidence that drinking to thirst, even during prolonged exercise under hot ambient conditions, will allow maintenance of proper hydration[10,11,20,26] and will attenuate thermal and circulatory strain.[2] Proper fluid intake during exercise need not be complicated – listen to your body and it will tell you when you need to drink. By doing so, you will avoid both dehydration and overhydration.

4. Programmed drinking can be dangerous

It is not unusual to come across recommendations that endurance athletes should use "programmed" drinking. Typically, this advice is to determine sweat rate by measuring body weight before and after a timed workout, and then drink in competitions at this calculated sweat rate so that the water lost in sweat is fully replaced. First, it should be evident that replacing all water lost in sweat should not be the goal, as this will result in overhydration. But, beyond that, sweat rate also varies considerably across conditions. Consider a situation in which you have presumed you need to match all of your weight loss during exercise with fluid intake, and you have calculated that your rate of sweat loss is 1000 ml per hour. But, the conditions during your race are a bit different than your test conditions and you have overestimated your needs by 25% (250 ml per hour). If you drink that full 1000 ml per hour, then in 4 hours, you have consumed a full liter (~1.4% body weight) more than necessary to keep your weight constant. Then, recognizing that you should have lost ~1-2% of body weight to keep the body water pool stable, you would have actually overhydrated by over 2% of your body weight during this 4-hour time period. Under the right circumstances, that could induce symptomatic EAH, as in a case we observed and have described.[9] It is far better to simply drink to thirst than to try to rely on a programmed drinking approach.

5. Supplemental sodium intake is not generally necessary

Sodium intake during exercise will drive thirst and may help prevent weight loss, but supplemental sodium has been demonstrated to not be necessary during prolonged exercise even under hot conditions for up to 30 hours.[11,13] The sodium consumed during meals should be adequate to replace losses during routine exercise[4] and the sodium taken in with a typical ultramarathon race diet allows for avoidance of salt-depletion dehydration.[11,13] Furthermore, sodium intake during exercise will not prevent EAH in the presence of overhydration.[14,27] Excessive sodium intake may even increase the likelihood of overconsumption of fluids leading to overhydration and an increased risk of developing EAH.[9,14] This may occur from the combined effects of gastrointestinal and/or hepatic-portal osmoreceptors providing an early stimulus of thirst without elevation in blood osmolality,[16,24,25] fluid retention from non-osmotically stimulated secretion of arginine vasopressin[6] and sodium loss in the urine from secretion of brain natriuretic peptide.[5,14,29]

6. Dehydration is not generally a cause of heat illness

Dehydration results in a lower sweating rate for a given core temperature.[21] This has raised concern for the potential that heat dissipation through evaporative cooling could be reduced if fluid replacement during exercise is insufficient. However, it is now recognized that severe heat illness during exercise is most likely to occur during high intensity activities, and can occur without dehydration.[1] Furthermore, there is no reason to believe that excessive fluid ingestion will prevent serious heat illness.[19] Our work has shown that serious elevations in core temperature seem to not be a concern during the relatively low intensity exercise of an ultramarathon, even under hot conditions.[28] Simply drinking water as desired during prolonged exercise will be adequate to prevent serious elevations in core temperature.[2]

7. Dehydration or electrolyte loss is not generally a cause of muscle cramping

Growing evidence from experimental[3,17] and cohort[22,23] studies suggests that muscle cramping related to endurance exercise results from neurological changes rather than uncompensated water and sodium losses incurred during exercise. Our work showing that 100-mile ultramarathon runners with muscle cramping had higher post-race plasma creatine kinase concentrations than those without cramping provides evidence that those developing cramping are placing greater demands on their muscles relative to their current state of training.[12] Our findings of a lack of difference between those with and without cramping in body weight change, post-race plasma sodium concentration, sodium supplement intake and total sodium intake provides further evidence that exercise-associated muscle cramping is not generally related to fluid and sodium imbalances under such conditions.[12,15] At present, the thought is that if you want to avoid muscle cramping, then be appropriately trained and compete within your level of training. If you develop muscle cramping during the event, then stretching the muscle along with a brief rest or reduction in intensity will often control the cramping.

8. Limited urination is not necessarily a signal of dehydration

Urine production should be reduced and concentrated during exercise as a result of shunting of blood away from internal organs towards exercising muscles and to the skin for removal of heat. But, it can be challenging to know the extent to which a reduction in urine production can be of concern. Key in this discussion is the recognition that reduced urine production to some extent is normal. Equally important is a recognition that urine production will also be reduced as EAH is developing because this condition is associated with the non-osmotically stimulated secretion of arginine vasopressin,[6] which serves to reduce urine production. Under such circumstances, a presumption that more fluid intake is necessary will only make the situation worse by increasing the extent of dilutional hyponatremia. Monitoring body weight change can help clarify if one might be dehydrated or overhydrated. But, given that accurate weight scales are typically not available, the amount of fluid consumed relative to the demands should be considered in assessing if one might be overhydrating or dehydrating.

9. Carry enough water between water sources to support thirst

It is important to avoid being without access to fluids during prolonged exercise. Under certain race conditions, this will mean that it is necessary to estimate the volume of fluids that must be carried between the available water sources. Obviously, you want to balance the need for access to water with avoidance of unnecessary weight carrage in the form of water. Determining the amout of water you should carry is best achieved by learning your personal needs so that you can accurately estimate the volume you might require, keeping in mind that the volume is dependent on exercise intensity and environmental conditions.

References

1. American College of Sports Medicine, Armstrong LE, Casa DJ, et al. American College of Sports Medicine position stand. Exertional heat illness during training and competition. Med Sci Sports Exerc 2007;39:556-72
2. Armstrong LE, Maresh CM, Gabaree CV, et al. Thermal and circulatory responses during exercise: effects of hypohydration, dehydration, and water intake. J Appl Physiol 1997;82:2028-35
3. Braulick KW, Miller KC, Albrecht JM, et al. Significant and serious dehydration does not affect skeletal muscle cramp threshold frequency. Br J Sports Med 2013;47:710–4
4. Casa DJ, DeMartini JK, Bergeron MF, et al. National Athletic Trainers' Association position statement: exertional heat illnesses. J Athl Train 2015;50(9):986-1000
5. Harris G, Reid S, Sikaris K, McCrory P. Hyponatremia is associated with higher NT-proBNP than normonatremia after prolonged exercise. Clin J Sport Med 2012;22:488-94
6. Hew-Butler T, Rosner MH, Fowkes-Godek S, et al. Statement of the 3rd International Exercise-Associated Hyponatremia Consensus Development Conference, Carlsbad, California, 2015. Clin J Sport Med 2015;25(4):303-20
7. Hoffman MD, Goulet ED, Maughan RJ. Don't lose more than 2% of body mass during ultra-endurance running. Really? Int J Sports Physiol Perform 2017;12(Suppl 1);S2-3
8. Hoffman MD, Hew-Butler T, Stuempfle KJ. Exercise-associated hyponatremia and hydration status in 161-km ultramarathoners. Med Sci Sports Exerc 2013;45:784-91
9. Hoffman MD, Myers TM. Case Study: Symptomatic exercise-associated hyponatremia in an endurance runner despite sodium supplementation. Int J Sport Nutr Exerc Metab 2015;25(6):603-6
10. Hoffman MD, Stuempfle KJ. Hydration strategies, weight change and performance in a 161 km ultramarathon. Res Sports Med 2014;22:213-25
11. Hoffman MD, Stuempfle KJ. Is sodium supplementation necessary to avoid dehydration during prolonged exercise in the heat? J Strength Cond Res 2016;30(3):615-20
12. Hoffman MD, Stuempfle KJ. Muscle cramping during a 161-km ultramarathon: Comparison of characteristics of those with and without cramping. Sports Med Open 2015;1(1):8. Epub 2015 May 21. PMID: 26284165
13. Hoffman MD, Stuempfle KJ. Sodium supplementation and exercise-associated hyponatremia during prolonged exercise. Med Sci Sports Exerc 2015;47(9):1781-7
14. Hoffman MD, Stuempfle KJ, Sullivan K, Weiss RH. Exercise-associated hyponatremia with exertional rhabdomyolysis: importance of proper treatment. Clin Nephrol 2015;83(4):235-42
15. Hoffman MD, Stuempfle KJ, Valentino T. Sodium intake during an ultramarathon does not prevent muscle cramping, dehydration, hyponatremia, or nausea. Sport Med Open 2015;1:39. Epub 2015 Dec 22. PMID: 26709371
16. Kraly FS, Kim YM, Dunham LM, Tribuzio RA. Drinking after intragastric NaCl without increase in systemic plasma osmolality in rats. Am J Physiol 1995;269(5 Pt 2):R1085-92
17. Miller KC, Mack GW, Knight KL, et al. Three percent hypohydration does not affect threshold frequency of electrically induced cramps. Med Sci Sports Exerc 2010;42(11):2056-63

18. Noakes TD, Sharwood K, Speedy D, et al. Three independent biological mechanisms cause exercise-associated hyponatremia: evidence from 2,135 weighed competitive athletic performances. Proc Natl Acad Sci U S A 2005;102:18550–5
19. Nolte HW, Hew-Butler T, Noakes TD, Duvenage CS. Exercise-associated hyponatremic encephalopathy and exertional heatstroke in a soldier: High rates of fluid intake during exercise caused rather than prevented a fatal outcome. Phys Sportsmed 2015;43(1):93-8
20. Nolte HW, Noakes TD, van Vuuren B. Protection of total body water content and absence of hyperthermia despite 2% body mass loss ('voluntary dehydration') in soldiers drinking ad libitum during prolonged exercise in cool environmental conditions. Br J Sports Med 2011;45:1106-12
21. Sawka MN. Physiological consequences of hypohydration: exercise performance and thermoregulation. Med Sci Sports Exerc 1992;24(6):657-70
22. Schwellnus MP, Allie S, Derman W, Collins M. Increased running speed and pre-race muscle damage as risk factors for exercise-associated muscle cramps in a 56 km ultra-marathon: a prospective cohort study. Br J Sports Med 2011; 45(14):1132-6
23. Schwellnus MP, Nicol J, Laubscher R, Noakes TD. Serum electrolyte concentrations and hydration status are not associated with exercise associated muscle cramping (EAMC) in distance runners. Br J Sports Med 2004;38(4):488-92
24. Stricker EM, Callahan JB, Huang W, Sved AF. Early osmoregulatory stimulation of neurohypophyseal hormone secretion and thirst after gastric NaCl loads. Am J Physiol Regul Integr Comp Physiol 2002;282(6):R1710-7
25. Stricker EM, Hoffmann ML, Riccardi CJ, Smith JC. Increased water intake by rats maintained on high NaCl diet: analysis of ingestive behavior. Physiol Behav 2003;79(4-5):621-31
26. 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;21:218-25
27. Twerenbold R, Knechtle B, Kakebeeke TH, et al. Effects of different sodium concentrations in replacement fluids during prolonged exercise in women. Br J Sports Med 2003;37:300-3
28. Valentino TR, Stuempfle KJ, Kern M, Hoffman MD. The influence of hydration state on thermoregulation during a 161-km ultramarathon. Res Sports Med. 2016;24(3):212-21
29. Zelingher J, Putterman C, Ilan Y, et al. Case series: hyponatremia associated with moderate exercise. Am J Med Sci 1996;311(2):86-91