Taylor & Francis
Taylor & Francis Group

The Physician and Sportsmedicine

ISSN: 0091-3847 (Print) 2326-3660 (Online) Journal homepage: http://www.tandfonline.com/loi/ipsm20

Are we being drowned by overhydration advice on the Internet?

Martin D. Hoffman, Theodore L. Bross III & R. Tyler Hamilton

To cite this article: Martin D. Hoffman, Theodore L. Bross III & R. Tyler Hamilton (2016): Are we being drowned by overhydration advice on the Internet?, The Physician and Sportsmedicine, DOI: 10.1080/00913847.2016.1222853

To link to this article: http://dx.doi.org/10.1080/00913847.2016.1222853

Accepted author version posted online: 10 Aug 2016.
Published online: 22 Aug 2016.

THE PHYSICIAN AND SPORTSMEDICINE, 2016
http://dx.doi.org/10.1080/00913847.2016.1222853

Taylor & Francis
Taylor & Francis Group

CLINICAL FEATURE
ORIGINAL RESEARCH

Are we being drowned by overhydration advice on the Internet?

Martin D. Hoffman[a], Theodore L. Bross, III[b] and R. Tyler Hamilton[c]

[a]Department of Physical Medicine & Rehabilitation, Department of Veterans Affairs, Northern California Health Care System, University of California Davis Medical Center, Sacramento, CA, USA; [b]Wright State University, Boonshoft School of Medicine, Dayton, OH, USA; [c]The School of Education and Behavioral Studies, Palm Beach Atlantic University, West Palm Beach, FL, USA

ABSTRACT

Objective: Because inappropriate recommendations about hydration during exercise appear widespread and potentially dangerous, we assessed the quality of a sampling of information currently available to the public on the Internet.

Methods: Internet searches using the Google search engine were conducted using the terms "hydration," "hydration guidelines," "drinking fluids" and "drinking guidelines" combined with "and exercise." From the first 50 websites for each search phrase, duplicates were removed yielding 141 unique websites that were categorized by source and examined for specific hydration related information and recommendations.

Results: Correct endorsement was as follows (reported as percent endorsing the concept relative to the number of websites addressing the issue): some weight loss should be expected during exercise (69.5% of 95), fluid consumption during exercise should be based upon thirst (7.3% of 110), electrolyte intake is not generally necessary during exercise (10.4% of 106), dehydration is not generally a cause of heat illness (3.4% of 58) or exercise-associated muscle cramping (2.4% of 42), exercise-associated muscle cramping is not generally related to electrolyte loss (0.0% of 16), and overhydration is a risk for hyponatremia (100.0% of 61). Comparison of website information from medical or scientific sources with that from other sources revealed no differences ($p = 0.4$ to 1.0) in the frequency of correct endorsement of the examined criteria.

Conclusion: Prevalent misinformation on the Internet about hydration needs during exercise and the contribution of hydration status to the development of heat illness and muscle cramping fosters overhydration. In general, those websites that should be most trusted by the public were no better than other websites at providing accurate information, and the potential risk of hyponatremia from overhydration was noted by less than half the websites. Since deaths from exercise-associated hyponatremia should be preventable through avoidance of overhydration, dissemination of a more appropriate hydration message is important.

ARTICLE HISTORY
Received 7 November 2015
Accepted 8 August 2016
Published online 23 August 2016

KEYWORDS
Dehydration; exercise; hyponatremia; sodium; water-electrolyte imbalance

1. Introduction

Symptomatic exercise-associated hyponatremia (EAH) has been reported in a wide range of endurance and other physical activities [1,2]. Confirmed deaths due to complications from EAH have occurred associated with participation in marathons, a canoe race, an Ironman triathlon, hiking, military exercises, police training, and American football [1–6]. It is now clear that the primary underlying risk factor for development of symptomatic EAH is sustained and excessive fluid (water or sports drinks) intake in volumes greater than that lost through sweating, respiration, and renal excretion so that a positive fluid balance accrues over time [2]. As such, the condition should be totally preventable by avoidance of overhydration [1,2].

Morbidity and mortality from EAH continues to result from the propagation of inaccurate information about proper hydration during exercise, lack of attention to the potential risks from overhydration, and omission of information about EAH in guidelines on hydration during exercise. As was the case for the two deaths from EAH among high school American football players in August 2014 [3,6], most of the symptomatic cases of EAH likely arise out of misunderstandings about proper hydration during exercise coupled with an undue concern about dehydration and/or heat illness, or an incorrect understanding of the pathophysiology of exercise-associated muscular cramping. Such misperceptions have been demonstrated among runners when examining their hydration-related knowledge [7–10], and overhydration has been shown to be common during endurance and ultraendurance competitions [11,12]. The report of a death of an Ironman triathlete in July 2015 further highlights the extent of the misunderstanding, even among medical professionals, with indication that insufficient salt intake was the underlying cause of the EAH [4]. Potential consequences from omission of information about EAH became evident from our report of a hiker who nearly died when her EAH was exacerbated by treatment for presumed dehydration and heal illness with

CONTACT Martin D. Hoffman mdhoffman@ucdavis.edu Department of Physical Medicine & Rehabilitation (117), Sacramento VA Medical Center, 10535 Hospital Way, Sacramento, CA 95655-1200, USA

oral fluids based upon a wilderness medicine field guidebook that failed to include any information about EAH [13].

Recognizing that the proper message about hydration during exercise is not reaching some groups, the primary purpose of this work was to document and comment upon the quality of information currently available to the general public related to hydration during exercise under the typical conditions in which fluids are readily available during the exercise. Specifically, we assessed the information on the Internet that individuals would discover when seeking recommendations about the quantity and type of fluids and electrolytes to consume during exercise with attention to information that could promote overhydration if inappropriately presented. Secondarily, we sought to appraise the quality of information provided by medical or scientific organizations, peer-reviewed publications, and medical professional individuals or facilities compared with the information from other sources.

2. Methods

2.1. Experimental approach and procedures

Internet searches were conducted using the Google search engine with the phrases 'hydration and exercise,' 'hydration guidelines and exercise,' 'drinking fluids and exercise,' and 'drinking guidelines and exercise' in December 2014. Our analysis was limited to the first 50 websites for each search phrase under the premise that most people would not explore beyond this number of sites. From these first 50 websites for each search phrase, duplicates were removed yielding 141 unique websites. Websites were then categorized and examined for specific information independently by two of the authors. When a discrepancy was present between these two authors on the assessment of specific hydration-related information (5.1% of items examined), the website was reexamined by both individuals with an effort to reach consensus. In all cases, consensus was achieved after this reexamination.

2.2. Website categorization

Websites were categorized by source into one of the following groups: medical or scientific organization, peer-reviewed publication, medical professional individual or facility, the media (i.e. online news of magazine article), sports organization or coach, sports drink and/or electrolyte replacement manufacturer, and others.

2.3. Assessment of hydration-related information

Each website was examined for agreement, disagreement, or lack of comment on the following hydration-related statements which we believe to be accurate based on current knowledge. With regard to the statements indicating that some factor is 'not generally' necessary or is a cause, we considered agreement with the statement to include situations where the factor was indicated to be a possible necessity or cause under some circumstances but was not suggested as always being a necessity or cause.

2.4. Some weight loss should be expected during exercise

The oxidation of stored fuel during exercise results in mass loss. Furthermore, production of metabolic water during fuel oxidation and the release of water with the breakdown of muscle and liver glycogen help to maintain the body's total water pool during exercise [14]. In fact, it has been shown that total body water was maintained despite a loss in body weight of ~3.5% among runners participating in a 56-km ultramarathon [15] and a loss in body weight of ~2% among soldiers during a 14.6-km march [16]. In another study, subjects dehydrated to 3% loss in baseline body weight finished a 25-km bike ergometer time trial at the same blood volume whether or not they started the time trial after reinfusion of saline to return them to baseline body mass [17]. These studies suggest that at least some of the intracellular water liberated during glycogen oxidation will follow the osmotic gradient into the circulating blood volume. As a result, some weight loss is appropriate during exercise for maintenance of proper hydration and avoidance of overhydration.

2.4.1. Fluid consumption during exercise should be based upon thirst

Thirst is an evolutionarily developed and precisely regulated mechanism that protects plasma osmolality and circulating blood volume [18]. 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 [19–22], recent guidelines for hydration during exercise under conditions when fluids are readily available recommend drinking to thirst for prevention of both dehydration and overhydration [1,2]. 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 [2]. There is now ample evidence that drinking to thirst, even during prolonged exercise under hot ambient conditions, will allow maintenance of proper hydration [15,16,23,24] and will attenuate thermal and circulatory strain [25].

2.4.2. Electrolyte intake is not generally necessary during exercise

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 h [24–26]. The sodium consumed during meals should be adequate to replace losses during exercise and allow for avoidance of salt-depletion dehydration [27]. Furthermore, sodium intake during exercise will not prevent EAH in the presence of overhydration [28,29]. Excessive sodium intake may even increase the likelihood of overconsumption of fluids leading to overhydration and an increased risk of developing EAH [28,30]. 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 [31–33], fluid retention from non-osmotically stimulated secretion of arginine vasopressin

[1,2], and sodium loss in the urine from secretion of brain natriuretic peptide [28,34,35].

2.4.3. Dehydration is not generally a cause of heat illness during exercise

Sweating rate is lower for a given core temperature with dehydration [36], which 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 [37]. Furthermore, there is no reason to believe that excessive fluid ingestion will prevent serious heat illness [38]. Recent work has also shown that while dehydration of 3% body weight resulted in statistically higher core temperatures than a euhydrated state during the latter portion of a 25-km bike ergometer time trial in a hot environment, the difference of 0.1–0.3°C, with peak core temperatures remaining well below hyperthermic levels, was thought to be unlikely to impact exercise performance or health [17]. Besides, an elevation in core temperature during exercise as a result of forced dehydration is eliminated by simply drinking water as desired during the exercise [25].

2.4.4. Dehydration or electrolyte loss is not generally a cause of exercise-associated muscle cramping

Growing evidence from experimental [39,40] and cohort [41,42] studies suggests that exercise-associated muscle cramping results from neurological changes rather than uncompensated water and sodium losses incurred during exercise [27]. Findings of higher postrace plasma creatine kinase concentrations among ultramarathon runners with muscle cramping during the race compared to those without cramping provide evidence that those developing cramping are placing relatively greater demands on their muscles relative to their current state of training [43]. A lack of difference between those with and without cramping in body weight change, postrace 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 [43,44].

2.4.5. Overhydration is a risk for hyponatremia

While it is presently unclear if sodium depletion might play a role in the development of EAH during very prolonged exercise [2], it is clear that the primary underlying etiological factor for symptomatic EAH is sustained fluid (water or sports drinks) intake in volumes greater than loss through sweating, respiration, and renal excretion so that a positive fluid balance accrues over time [1,2]. For most athlete-related symptomatic cases of EAH, impaired water clearance due to non-osmotic secretion of arginine vasopressin is an important contributing factor [1,2]. While EAH is frequently documented in association with hypovolemia [11,12], symptomatic EAH is virtually exclusively seen in those who gain or lose inadequate weight during exercise as a result of overhydration [12,28]. Thus, there should be no debate that overhydration is a risk for the development of symptomatic EAH.

Websites were also assessed for comment on the extent of weight loss that should be avoided during exercise. It has been estimated that at least a 2–3% weight loss should be expected during prolonged exercise [11,12], while less weight loss would be appropriate during shorter bouts of exercise.

Table 1. Distribution of categories of the 141 websites that were examined.

Category	*n*	%
Media	20	14.2
Medical or scientific organization	19	13.5
Sports organization or coach	15	10.6
Peer-reviewed publication	11	7.8
Medical professional individual or facility	10	7.1
Sports drink and/or electrolyte replacement manufacturer	6	4.3
Other	60	42.6

2.5. Analysis of data

Between-group comparisons were made with the Fisher's exact test. Statistical significance was set at $p < 0.05$.

3. Results

3.1. Website categories

The category distribution of the 141 websites that were examined is shown in Table 1. Over a fourth (28.4%) were from a medical or scientific organization, peer-reviewed publication, or medical professional individual or facility.

3.2. Hydration information

The hydration-related information being espoused on the Internet is summarized in Tables 2 and 3. Over two-thirds of the websites addressed whether or not weight loss during exercise should occur, fluid consumption should be based on thirst, and electrolyte intake is necessary during exercise. Of those addressing the issues, most (69.5%) noted that some weight loss should occur during exercise, but few indicated that fluid consumption should be based on thirst (7.3%) and that electrolyte intake is not generally necessary during exercise (10.4%). Less than half of the websites addressed the other hydration-related information examined, and few noted that dehydration is not generally a cause of heat illness (3.4%) or exercise-associated muscle cramping (2.4%), or that exercise-associated muscle cramping is not generally related to electrolyte loss (0%). With regard to overhydration as a risk factor for EAH, only 61 websites (43.3%) commented on the issue, but each of those websites correctly acknowledged overhydration as a risk for EAH.

Less than half (69 of 141 or 48.9%) of the websites provided a recommendation about the amount of weight loss to be avoided during exercise. Of those addressing the issue, the indicated weight loss that should be avoided during exercise was ≥0–1% for 23 (33.3%) websites, ≥2% for 44 (63.8%) websites, and ≥3% for 2 (2.9%) websites.

3.3. Comparison of information quality by source

Comparison of hydration-related information from those in the categories of medical or scientific organization, peer-reviewed publication, and medical professional individual or facility was compared with all other websites. There was no

Table 2. Endorsement of the examined hydration-related information and recommendations by the different website categories.

	Information item (% endorsing the criteria/number addressing the criteria)						
Category	1	2	3	4	5	6	7
Media (n = 20)	84.6/13	25.0/16	20.0/15	0.0/6	16.7/6	0.0/2	100.0/12
Medical or scientific organization (n = 19)	64.3/14	0.0/15	5.9/17	0.0/11	0.0/8	0.0/2	100.0/8
Sports organization or coach (n = 15)	60.2/13	7.7/13	0.0/12	12.5/8	0.0/4	0.0/2	100.0/7
Peer-reviewed publication (n = 11)	85.7/7	16.7/6	0.0/5	0.0/2	0.0/2	0.0/2	100.0/3
Medical professional individual or facility (n = 10)	66.7/6	0.0/9	11.1/9	0.0/3	0.0/4	0.0/2	100.0/3
Sports drink and/or electrolyte replacement manufacturer (n = 6)	100.0/3	0.0/6	0.0/6	0.0/2	0.0/2	0.0/2	100.0/3
Other (n = 60)	61.5/39	4.4/45	14.3/42	3.8/26	0.0/16	0.0/4	100.0/25
Overall (n = 141)	69.5/95	7.3/110	10.4/106	3.4/58	2.4/42	0.0/16	100.0/61

Information items are numbered as follows:
(1) Some weight loss should be expected during exercise.
(2) Fluid consumption during exercise should be based upon thirst.
(3) Electrolyte intake is not necessary during exercise.
(4) Dehydration is not generally a cause of heat illness during exercise.
(5) Dehydration is not generally a cause of exercise-associated muscle cramping.
(6) Electrolyte loss is not generally a cause of exercise-associated muscle cramping.
(7) Overhydration is a risk for hyponatremia.

Table 3. Recommended amount of weight loss to be avoided during exercise by the different website categories.

	Recommended amount of weight loss to be avoided (% endorsing)				
Category	Not specified	>0%	≥1%	≥2%	≥3%
Media (n = 20)	65.0	0.0	5.0	25.0	5.0
Medical or scientific organization (n = 19)	47.4	5.3	10.5	36.8	0.0
Sports organization or coach (n = 15)	33.3	6.7	20.0	40.0	0.0
Peer-reviewed publication (n = 11)	54.5	9.1	9.1	27.3	0.0
Medical professional individual or facility (n = 10)	60.0	0.0	20.0	20.0	0.0
Sports drink and/or electrolyte replacement manufacturer (n = 6)	16.7	0.0	0.0	83.3	0.0
Other (n = 60)	53.3	5.0	13.3	26.7	1.7
Overall (n = 141)	51.1	4.3	12.1	31.2	1.4

statistical difference (p = 0.4–1.0) in the frequency of endorsement of the information examined between these two groups of information sources.

4. Discussion

Athletes and noncompetitive exercisers get information about hydration during exercise from various sources [7–10], which undoubtedly include the Internet. The Internet abounds with consumer health information and recommendations and has been increasingly utilized by the public to assist with their medical needs. Yet, there have been long-standing concerns about the quality of medical information from this source [45,46]. It should therefore be no surprise that information about hydration needs during exercise is widely available on the Internet and that much of the information is inaccurate.

The present appraisal confirms that the Internet propagates misinformation about hydration needs during exercise. Most concerning is the finding that only 43.3% of websites from Internet searches about hydration needs during exercise acknowledged overhydration as a risk for EAH which has been known to be the case for over a decade [47]. Furthermore, of those websites providing recommendations about the extent of weight loss that should be avoided during exercise, 33.3% indicated that no more than 0–1% of body weight should be lost while exercising. Few websites noted that fluid consumption should be based on thirst, or that dehydration is not generally a cause of heat illness or muscle cramping. Thus, it is evident that overhydration during exercise is a common message on the Internet. To make matters worse, those websites that would generally be perceived as being most trustworthy by the public appear to be no better than other websites at providing accurate hydration-related information. It should therefore be of no surprise that athletes often have misunderstandings about proper hydration during exercise [7–10].

Prior work beginning in the 1990s has raised concern about the promotion of overhydration during exercise [48]. The concepts about hydration needs during exercise that were evident in the environments of two high school American football players succumbing from dilutional EAH in 2014 [3,6] demonstrate that such misguided advice remains within the culture of some environments. The findings of the current analysis showing that there is continued widespread propagation of a message that encourages excessive fluid intake during exercise help explain why that might be. Given that overhydration is the key mechanism for the development of the potentially life-threatening disorder of EAH [1,2], it is critical to continue to work toward the general dissemination of a more appropriate message about hydration needs during exercise, the importance of which has been emphasized in a recent debate [19,21] and consensus papers [1,2].

We acknowledge some potential limitations to this work. We have provided support for the hydration-related statements we assessed and believe that these statements accurately reflect current knowledge. However, there will be individuals who may challenge some of the statements about hydration during exercise that we accepted as factual for this work, perhaps because some professional organizations have yet to embrace recent information in consensus documents or due to potential conflicts of interest previously discussed [49,50]. Nevertheless, there should be no

controversy that overhydration is the primary underlying risk factor for development of symptomatic EAH, and regardless of what one believes as the stimulus for the overhydration, there should be universal agreement that it is problematic when less than half of the websites examined provided any cautionary note about overhydration as a risk for EAH. We also acknowledge that our methods, which used a consensus of two researchers in evaluating the website information, offered an opportunity for biased interpretation. However, we believe that this potential bias was limited since these two investigators had not previously published on this topic. Furthermore, the fact that initial agreement among the two investigators was present nearly 95% of the time from independent assessments offers additional support for our approach.

5. Conclusion

Much of the information on the Internet about hydration needs during exercise continues to promote overhydration, which is the key stimulus for development of symptomatic EAH. Since deaths from EAH should be entirely preventable by avoidance of overhydration, efforts to disseminate a more appropriate hydration message remain warranted.

Acknowledgments

This material is the result of work supported with resources and the use of facilities at the VA Northern California Health Care System. The contents reported here do not represent the views of the Department of Veterans Affairs or the United States Government.

Funding

This article has received no external funding.

Declaration of interest

The authors have no relevant affiliations or financial involvement with any organization or entity with a financial interest in or financial conflict with the subject matter or materials discussed in the manuscript. This includes employment, consultancies, honoraria, stock ownership or options, expert testimony, grants or patents received or pending, or royalties.

References

1. Bennett BL, Hew-Butler T, Hoffman MD, et al. Wilderness Medical Society practice guidelines for treatment of exercise-associated hyponatremia: 2014 update. Wilderness Environ Med. 2014;25(4 Suppl):S30–S42.
2. 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):303–320.
3. Blevins R, Apel T Doctor: Wilbanks' death unpreventable, freak occurrence. The Clarion-Ledger [updated 2014 Aug 27]. [cited 2015 Nov 7]. Available from: http://www.clarionledger.com/story/prepsreport/2014/08/25/walker-wilbanks-cause-of-death-related-to-over-hydration/14598215/.
4. Krabel H Athlete dies after IM Frankfurt. Slowtwitch.com updated 2015 Jul 8; cited 2015 Nov 7]. Available from: http://www.slowtwitch.com/News/Athlete_dies_after_IM_Frankfurt_5190.html.
5. Myers TM, Hoffman MD. Hiker fatality from severe hyponatremia in Grand Canyon National Park. Wilderness Environ Med. 2015;26(3):371–374.
6. Stevens A Update: Douglas County football player has died. The Atlanta Journal-Constitution [updated 2014 Aug 11; cited 2015 Nov 7]. Available from: http://www.ajc.com/news/news/family-douglas-county-football-player-has-no-brain/ngy2X/.
7. O'Neal EK, Wingo JE, Richardson MT, et al. Half-marathon and full-marathon runners' hydration practices and perceptions. J Athl Train. 2011;46(6):581–591.
8. Williams J, Tzortziou Brown V, Malliaras P, et al. Hydration strategies of runners in the London Marathon. Clin J Sport Med. 2012;22(2):152–156.
9. Winger JM, Dugas JP, Dugas LR. Beliefs about hydration and physiology drive drinking behaviours in runners. Br J Sports Med. 2011;45(8):646–649.
10. Winger JM, Hoffman MD, Hew-Butler TD, et al. The effect of physiology and hydration beliefs on race behavior and postrace sodium in 161-km ultramarathon finishers. Int J Sports Physiol Perform. 2013;8(5):536–541.
11. Hoffman MD, Hew-Butler T, Stuempfle KJ. Exercise-associated hyponatremia and hydration status in 161-km ultramarathoners. Med Sci Sports Exerc. 2013;45:784–791.
12. 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;102:18550–18555.
13. Hoffman MD, Myers TM. Near-fatal outcome from absence of information about exercise-associated hyponatremia in a wilderness medicine field guidebook. Wilderness Environ Med. 2015;26(2):284–285.
14. 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.
15. 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;21:218–225.
16. 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;45:1106–1112.
17. Wall BA, Watson G, Peiffer JJ, et al. Current hydration guidelines are erroneous: dehydration does not impair exercise performance in the heat. Br J Sports Med. 2015;49:1077–1083.
18. Fitzsimons JT. Angiotensin, thirst, and sodium appetite. Physiol Rev. 1998;78:583–686.
19. Hoffman MD, Cotter JD, Goulet ÉD, et al. View: is drinking to thirst adequate to appropriately maintain hydration status during prolonged endurance exercise? Yes. Wilderness Environ Med. 2016;27(2):192–195.
20. Armstrong LE, Johnson EC, Bergeron MF. Counterview: is drinking to thirst adequate to appropriately maintain hydration status during prolonged endurance exercise? No. Wilderness Environ Med. 2016;27(2):195–198.
21. Hoffman MD, Cotter JD, Goulet ÉD, et al. Rebuttal from "Yes". Wilderness Environ Med. 2016;27(2):198–200.
22. Armstrong LE, Johnson EC, Bergeron MF. Rebuttal from "No". Wilderness Environ Med. 2016;27(2):200–202.
23. Hoffman MD, Stuempfle KJ. Hydration strategies, weight change and performance in a 161 km ultramarathon. Res Sports Med. 2014;22:213–225.
24. Hoffman MD, Stuempfle KJ. Is sodium supplementation necessary to avoid dehydration during prolonged exercise in the heat? J Strength Cond Res. 2016;30(3):615–620.
25. 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;82:2028–2035.
26. Hoffman MD, Stuempfle KJ. Sodium supplementation and exercise-associated hyponatremia during prolonged exercise. Med Sci Sports Exerc. 2015;47(9):1781–1787.

27. 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.
28. Hoffman MD, Stuempfle KJ, Sullivan K, et al. Exercise-associated hyponatremia with exertional rhabdomyolysis: importance of proper treatment. Clin Nephrol. 2015;83(4):235–242.
29. 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;37:300–303.
30. 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):603–606.
31. Kraly FS, Kim YM, Dunham LM, et al. Drinking after intragastric NaCl without increase in systemic plasma osmolality in rats. Am J Physiol. 1995;269(5 Pt 2):R1085–R1092.
32. Stricker EM, Callahan JB, Huang W, et al. Early osmoregulatory stimulation of neurohypophyseal hormone secretion and thirst after gastric NaCl loads. Am J Physiol Regul Integr Comp Physiol. 2002;282(6):R1710–R1717.
33. Stricker EM, Hoffmann ML, Riccardi CJ, et al. Increased water intake by rats maintained on high NaCl diet: analysis of ingestive behavior. Physiol Behav. 2003;79(4–5):621–631.
34. Harris G, Reid S, Sikaris K, et al.. Hyponatremia is associated with higher NT-proBNP than normonatremia after prolonged exercise. Clin J Sport Med. 2012;22:488–494.
35. Zelingher J, Putterman C, Ilan Y, et al. Case series: hyponatremia associated with moderate exercise. Am J Med Sci. 1996;311(2):86–91.
36. Sawka MN. Physiological consequences of hypohydration: exercise performance and thermoregulation. Med Sci Sports Exerc. 1992;24(6):657–670.
37. 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;39:556–572.
38. Nolte HW, Hew-Butler T, Noakes TD, et al. 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):93–98.
39. 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;47:710–714.
40. 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):2056–2063.
41. Schwellnus MP, Allie S, Derman W, et al.. 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):1132–1136.
42. Schwellnus MP, Nicol J, Laubscher R, et al.. 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):488–492.
43. 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
44. 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
45. Cline RJ1, Haynes KM. Consumer health information seeking on the Internet: the state of the art. Health Educ Res. 2001;16(6):671–692.
46. Silberg WM, Lundberg GD, Musacchio RA. Assessing, controlling, and assuring the quality of medical information on the Internet: Caveant lector et viewor–Let the reader and viewer beware. JAMA. 1997;277(15):1244–1245.
47. Hew-Butler T, Almond C, Ayus JC, et al. Consensus statement of the 1st International Exercise-Associated Hyponatremia Consensus Development Conference, Cape Town, South Africa 2005. Clin J Sport Med. 2005;15(4):208–213.
48. Beltrami FG, Hew-Butler T, Noakes TD. Drinking policies and exercise-associated hyponatraemia: is anyone still promoting overdrinking? Br J Sports Med. 2008;42(10):796–501. Erratum in: Br J Sports Med 2009;43(4):310–1.
49. Cohen D. The truth about sports drinks. BMJ. 2012 Jul;18:345:e4737.
50. Noakes TD. Changes in body mass alone explain almost all of the variance in the serum sodium concentrations during prolonged exercise. Has commercial influence impeded scientific endeavour? Br J Sports Med. 2011;45(6):475–477.