*Journal of Athletic Training* 2011:46(6):581–591

www.nata.org/jat



# Half-Marathon and Full-Marathon Runners' Hydration Practices and Perceptions

**Eric K. O'Neal, PhD*; Jonathan E. Wingo, PhD†; Mark T. Richardson†; James D. Leeper, PhD‡; Yasmine H. Neggers, PhD, RD§; Phil A. Bishop, EdD†**

*Department of Health, Physical Education and Recreation, University of North Alabama, Florence; †Department of Kinesiology, ‡Department of Community and Rural Medicine, §Department of Human Nutrition, University of Alabama, Tuscaloosa

***Context:*** The behaviors and beliefs of recreational runners with regard to hydration maintenance are not well elucidated.

***Objective:*** To examine which beverages runners choose to drink and why, negative performance and health experiences related to dehydration, and methods used to assess hydration status.

***Design*:** Cross-sectional study.

***Setting:*** Marathon registration site.

***Patients or Other Participants:*** Men (n = 146) and women (n = 130) (age = 38.3 ± 11.3 years) registered for the 2010 Little Rock Half-Marathon or Full Marathon.

***Intervention(s):*** A 23-item questionnaire was administered to runners when they picked up their race timing chips.

***Main Outcome Measure(s):*** Runners were separated into tertiles (Low, Mod, High) based on *z* scores derived from training volume, expected performance, and running experience. We used a 100-mm visual analog scale with anchors of 0 (*never*) and 100 (*always*). Total sample responses and comparisons between tertile groups for questionnaire items are presented.

***Results:*** The High group (58±31) reported greater consumption of sport beverages in exercise environments than the Low (42 ± 35 mm) and Mod (39 ± 32 mm) groups ($P < .05$) and perceived sport beverages to be superior to water in meeting hydration needs ($P < .05$) and improving performance during runs greater than 1 hour ($P < .05$). Seventy percent of runners experienced 1 or more incidents in which they believed dehydration resulted in a major performance decrement, and 45% perceived dehydration to have resulted in adverse health effects. Twenty percent of runners reported monitoring their hydration status. Urine color was the method most often reported (7%), whereas only 2% reported measuring changes in body weight.

***Conclusions:*** Greater attention should be paid to informing runners of valid techniques to monitor hydration status and developing an appropriate individualized hydration strategy.

***Key Words:*** dehydration, sport beverages, hydration monitoring

**Key Points**

- Most runners had experienced performance decrements that they attributed to dehydration. Almost half the runners had sustained heat-related illness symptoms that they related to dehydration.
- Despite these adverse events, few participants monitored their hydration levels or used specific hydration plans.
- Better dissemination of accurate scientific information about appropriate hydration practices may increase runners' safety.

Distance running has become increasingly popular among US adults. In 2009, more than 397 marathons took place in the United States, resulting in more than 468000 finishing times, a 10% increase from 2008.[1] The majority of these participants probably serve as their own coaches and are unlikely to be supervised by health care professionals. Currently, no consensus for hydration guidelines exists in the scientific community and, consequently, the information runners encounter varies greatly.[2] Past hydration guidelines[3] encouraged athletes to replace sweat losses during competition. These recommendations received much scrutiny from influential people in the running community,[4] some of whom believe that such messages encourage overdrinking and increase the incidence of hyponatremia among marathoners in the United States. More recent position stands for athletes[5–7] have been fairly conservative, emphasizing the need for sufficient fluid intake before, during, and after exercise to minimize loss of body weight between exercise bouts and recommending that consumption during exercise not exceed sweat losses but be sufficient to avoid body weight reduction greater than 2%. All 3 position stands also promoted the addition of carbohydrates and electrolytes to fluids when exercise is to be prolonged (approximately 1 hour or more) and large sweat losses are expected, and they advised incorporating various methods to measure hydration status (eg, urine specific gravity, urine color, and acute and day-to-day changes in body mass). However, the International Marathon Medical Directors Association[8] has presented opposing viewpoints, particularly advocating that thirst be used as the primary gauge for fluid intake and deemphasizing the relevance of sodium ingestion during events.

Organized road races of half-marathon distance or longer are typically scheduled during cooler times of the year and in cooler regions, so that sweat losses can be partially mitigated. Most courses also feature numerous aid stations that provide water and sport beverages. Such ready availability of fluids may result in runners actually gaining weight from the beginning to the end of a race; in some cases, they ingest enough fluid to develop hyponatremia.[9] However, during training runners are responsible for providing their own fluids, and consequently hydration opportunities may be more limited. Access to sufficient hydration can be a particular concern for runners who train in warmer weather.

Shendell et al[10] reported that almost 90% of marathon runners completed their long runs outdoors. Furthermore, highly trained runners were unlikely to replace the majority of fluid losses during training, even if fluids were accessible.[11] Large body water losses can lead to dehydration (known to impair cognitive function[12]) and are associated with increased risk of heat illness and decreased aerobic performance for physically active people in warm environments.[6,13] Furthermore, compounding the potential negative effects of dehydration is the fact that running is often a solitary endeavor, and the athlete may be alone and far from support when dehydration occurs; therefore, it is important that runners be well educated about adequate hydration during training and competition.

Little is known about the hydration practices of distance runners and the degree of influence that association guidelines have on their behaviors. Accordingly, the primary purposes of our investigation were to determine which beverages runners drink and why, whether runners have experienced decreases in performance or heat related-illness symptoms believed to be caused by dehydration, and how runners monitor their hydration status. We also examined differences in responses for these areas, based on running volume and experience and performance levels. Additionally, runners were asked which sources influenced their hydration strategy and beverage choice decision making and how they supplied themselves with fluids during runs.

## METHODS

### Research Design and Participants

A population representing "average" nonelite level distance runners was targeted for this study. Runners participating in the 2010 Little Rock, Arkansas, Half-Marathon and Marathon were surveyed on site during the exposition that occurred during the 2 days before the race. A table for participants to use to complete surveys and 2 signs describing the survey were located at the doorway to the entrance of the registration site. Three investigators approached race participants who were entering the exposition center hall to pick up their race bibs and timing chips or leaving the hall and explained the purpose and requirements of the study.

No qualification times were required for entry, so the race was open to everyone. A total of 2908 runners completed the half-marathon, and 1550 runners completed the marathon. The only inclusion criteria for this study were that participants be at least 18 years of age and registered to run the half-marathon or full marathon. The researchers verbally informed participants of the purpose of the study and inclusion criteria, and participants completed a consent form before taking the survey. Consent forms and surveys were turned in separately, in order to maintain anonymity. This investigation was approved by the university's institutional review board.

Three hundred runners completed surveys. However, 24 surveys were discarded because they contained incomplete items or were completed incorrectly. A total of 146 men and 130 women were included in the final sample; 57% (n = 157) were from Arkansas, and fewer than 1% (n = 2) were from foreign countries. The remaining participants claimed 27 different home states. Eighty-two percent of participants (n = 227) regularly engaged in exercise in hot or warm environments. Twenty-seven participants (10%) had been running the half-marathon distance or longer, during a race or training, for less than a year. Eleven percent of runners (n = 30) trained under the supervision of a coach or medical staff.

Participants were separated into tertiles by running volume, performance based on expected race completion time, and racing experience (VPE). The VPE was determined from a weighted *z* score based on expected categoric finishing time (weighted 35%; expected finishing times were categorized, with 1 representing the slowest category and 6 representing the fastest category), average miles per week (weighted 35%), participation in organized running events over the last 24 months (weighted 10%), years of running experience at half-marathon distance or longer (weighted 10%), and aerobic exercise sessions per week (weighted 10%). Runners' *z* scores were ranked and separated into tertiles (low = Low, n = 92; moderate = Mod, n = 92; and high = High, n = 92), based on the weighted *z* score, according to the 5 categories described. Demographic results are presented in Table 1.

### Survey Instrument

When we began to develop the survey, we were unaware of any instruments that addressed the areas of concern. The lead investigator (E.K.O.) created an original questionnaire constructed of items influenced by topics and content from recent reviews and position stands addressing fluid and nutritional concern for performance and prevention of heat-related illnesses.[5,6,13–16] The survey items were reviewed for readability and content by the co-investigators, who included people with research experience in nutrition and performance, environmental physiology, and thermoregulation. The review panel also consisted of experienced runners and a registered dietitian. Revisions were made, and the draft survey was evaluated by 3 male and 2 female runners. After completion of the survey, the runners were asked to report any items that lacked clarity and to offer suggestions on content. The final questionnaire consisted of 23 items.

The first item was a 100-mm visual analog scale asking participants whether they regularly drank sport beverages before, during, or immediately after exercise, with anchors of 0 (*never*) and 100 (*always*). A definition for *sport beverage* was provided in bold print immediately above this item: "For the purpose of this study, sport beverages will be defined as flavored beverages containing carbohydrates and electrolytes."

The second section asked participants the extent to which 6 different information sources influenced their exercise-related beverage choices and hydration strategies (Table 2). Participants chose from *none, minor,* and *major*.

The next section included 10 items that addressed types of beverages consumed by participants and their viewpoints on the ergogenic and hydration properties of water and sport beverages (Table 3). Response choices for this section were *strongly*

**Table 1. Participants' Demographics, Running Habits, Race Distances, and Predicted Finishing Times (N = 276)**

| Item | Group[a] | | | |
|---|---|---|---|---|
| | Low | Mod | High | Total |
| Age, y (mean ± SD) | 35.8 ± 10.5[b] | 38.9 ± 12.0 | 40.2 ± 11.3 | 38.3 ± 11.3 |
| Men/women, No. | 31/61 | 51/41 | 64/28 | 146/130 |
| Aerobic exercise sessions/wk (mean ± SD) | 4.0 ± 1.2[b,c] | 4.7 ± 1.5[b] | 6.0 ± 2.3 | 4.9 ± 1.9 |
| Exercise sessions/wk lasting longer than 1 h (mean ± SD) | 2.7 ± 1.6[b] | 3.0 ± 1.6[b] | 4.4 ± 2.3 | 3.4 ± 2.0 |
| Running miles/wk (mean ± SD) | 13.2 ± 4.9[b,c] | 22.9 ± 3.5[b] | 39.5 ± 11.1 | 25.2 ± 13.1 |
| Frequently train in hot or warm environment, % | 80.0 | 90.9 | 90.1 | 83.8 |
| Running half-marathon distance or longer, y (mean ± SD) | 2.9 ± 4.7[b,c] | 5.3 ± 5.7[b] | 7.5 ± 6.8 | 5.2 ± 6.1 |
| Running competitions of half-marathon distance or longer completed in last 24 mo (mean ± SD) | 2.1 ± 2.6[b] | 3.5 ± 4.1[b] | 8.8 ± 10.2 | 4.8 ± 7.1 |
| Training under the supervision of a coach or medical staff, % | 15 | 9 | 10 | 11 |
| Registered race distance, half-marathon/full marathon | 71/21 | 58/34 | 29/63 | 158/118 |
| Predicted finishing time, h (half-marathon/full marathon)[d] | | | | |
| <1.5/<3.0 | 0 | 0 | 8 | 8 |
| 1.5–1.75/3–3.5 | 1 | 6 | 25 | 32 |
| 1.75–2.0/3.5–4.0 | 11 | 21 | 20 | 52 |
| 2–2.25/4–4.5 | 26 | 40 | 21 | 87 |
| 2.25–2.5/4.5–5.0 | 25 | 17 | 9 | 51 |
| >2.5/>5.0 | 29 | 8 | 9 | 46 |
| Regularly drink sport beverages in exercise environments (0, never; 100, always) | 42 ± 35[b] | 39 ± 32[b] | 58 ± 31 | 46 ± 34 |

[a] Low, Mod, and High are tertile classifications based on training volume, expected performance, and running experience.

[b] Different from High ($P < .001$).

[c] Different from Mod ($P < .001$).

[d] Low different from Mod and High ($P < .0001$) and Mod different from High ($P < .001$).

**Table 2. Sources of Runners' Information on Hydration Strategies and Beverage Choice, % (N = 276)**

| Item | Response | Group[a] | | | |
|---|---|---|---|---|---|
| | | Low | Mod | High | Total |
| Advice of other runners about beverages and hydration strategies | None | 7 | 4 | 7 | 6 |
| | Minor | 28 | 32 | 32 | 31 |
| | Major | 65 | 64 | 62 | 64 |
| Advice of health professionals, such as athletic trainers or doctors, about beverage choice and hydration strategies | None | 15 | 23 | 12 | 17 |
| | Minor | 33 | 35 | 41 | 36 |
| | Major | 52 | 42 | 47 | 47 |
| Advice of former or current coaches or fitness professionals, such as personal trainers or fitness instructors, about beverages and hydration strategies | None | 21 | 24 | 24 | 23 |
| | Minor | 30 | 29 | 30 | 30 |
| | Major | 49 | 47 | 46 | 47 |
| Article about hydration and beverages in magazines, books, or newspapers | None | 33 | 19 | 17 | 23 |
| | Minor | 51 | 52 | 55 | 53 |
| | Major | 16 | 29 | 29 | 25 |
| Peer-reviewed research journal articles about beverages and hydration strategies | None | 36 | 35 | 23 | 31 |
| | Minor | 42 | 28 | 43 | 38 |
| | Major | 22 | 37 | 34 | 31 |
| Advertisements about beverages and hydration strategies from commercials or in magazines | None | 37 | 40 | 45 | 41 |
| | Minor | 57 | 55 | 49 | 54 |
| | Major | 7 | 4 | 7 | 6 |

[a] Low, Mod, and High are tertile classifications based on training volume, expected performance, and running experience.

**Table 3. Runners' Beverage Choices and Perceptions of Differences Between Water and Sport Beverages (N = 276)**

| Item | Response[b] | Group[a] Low | Mod | High | Total |
|---|---|---|---|---|---|
| 1. I intentionally increase the volumes of fluids I drink in non-exercise environments during periods of warm or hot weather. | Strongly disagree, % | 3 | 4 | 3 | 4 |
| | Disagree, % | 2 | 12 | 9 | 8 |
| | Agree, % | 52 | 47 | 63 | 54 |
| | Strongly agree, % | 36 | 34 | 25 | 32 |
| | Not applicable/do not know, % | 7 | 3 | 0 | 3 |
| | Mean ± SD | 3.3 ± 0.7 | 3.1 ± 0.8 | 3.1 ± 0.7 | 3.2 ± 0.7 |
| 2. Sport beverages are superior to water in meeting hydration needs of exercisers. | Strongly disagree, % | 11 | 7 | 0 | 6 |
| | Disagree, % | 23 | 33 | 30 | 31 |
| | Agree, % | 34 | 42 | 45 | 40 |
| | Strongly agree, % | 13 | 10 | 21 | 15 |
| | Not applicable/do not know, % | 13 | 9 | 4 | 8 |
| | Mean ± SD | 2.6 ± 0.9 | 2.6 ± 0.8[c] | 2.9 ± 0.7 | 2.7 ± 0.8 |
| 3. I prefer the taste of water over sport beverages in exercise environments. | Strongly disagree, % | 10 | 4 | 10 | 8 |
| | Disagree, % | 32 | 28 | 35 | 32 |
| | Agree, % | 26 | 34 | 39 | 33 |
| | Strongly agree, % | 27 | 30 | 13 | 24 |
| | Not applicable/do not know, % | 5 | 3 | 3 | 4 |
| | Mean ± SD | 2.7 ± 1.0 | 2.9 ± 0.9[c] | 2.6 ± 0.9 | 2.8 ± 0.9 |
| 4. I avoid drinking sport beverages because of their caloric content. | Strongly disagree, % | 19 | 23 | 27 | 23 |
| | Disagree, % | 37 | 44 | 39 | 40 |
| | Agree, % | 21 | 22 | 23 | 22 |
| | Strongly agree, % | 15 | 9 | 4 | 9 |
| | Not applicable/do not know, % | 9 | 3 | 7 | 6 |
| | Mean ± SD | 2.4 ± 1.0 | 2.2 ± 0.9 | 2.0 ± 0.9 | 2.2 ± 0.9 |
| 5. I dilute regular sport beverages with water. | Strongly disagree, % | 30 | 21 | 29 | 27 |
| | Disagree, % | 19 | 28 | 24 | 24 |
| | Agree, % | 24 | 17 | 20 | 20 |
| | Strongly agree, % | 9 | 24 | 21 | 18 |
| | Do not know, % | 19 | 10 | 6.5 | 12 |
| | Mean ± SD | 2.1 ± 1.0 | 2.5 ± 1.1 | 2.3 ± 1.1 | 2.3 ± 1.1 |
| 6. I drink low- or zero-calorie sport beverages. | Strongly disagree, % | 15 | 17 | 28 | 20 |
| | Disagree, % | 21 | 24 | 20 | 21 |
| | Agree, % | 35 | 37 | 30 | 34 |
| | Strongly agree, % | 17 | 13 | 17 | 16 |
| | Not applicable/do not know, % | 12 | 9 | 4 | 8 |
| | Mean ± SD | 2.6 ± 1.0 | 2.5 ± 1.0 | 2.4 ± 1.1 | 2.5 ± 1.0 |
| 7. I drink beverages marketed as "recovery" beverages that contain high percentages of carbohydrates or a carbohydrate and protein combination. | Strongly disagree, % | 14 | 25 | 17 | 19 |
| | Disagree, % | 27 | 35 | 28 | 30 |
| | Agree, % | 36 | 19 | 34 | 29 |
| | Strongly agree, % | 4 | 10 | 12 | 9 |
| | Not applicable/do not know, % | 19 | 12 | 9 | 13 |
| | Mean ± SD | 2.4 ± 0.8 | 2.1 ± 1.0 | 2.4 ± 0.9 | 2.3 ± 0.9 |
| 8. Drinking a sport beverage instead of water after exercise will result in better recovery and improved performance for my next exercise session. | Strongly disagree, % | 7 | 11 | 2 | 7 |
| | Disagree, % | 25 | 32 | 26 | 28 |
| | Agree, % | 39 | 34 | 47 | 40 |
| | Strongly agree, % | 7 | 10 | 15 | 11 |
| | Not applicable/do not know, % | 23 | 14 | 10 | 16 |
| | Mean ± SD | 2.6 ± 0.8 | 2.5 ± 0.9[c] | 2.8 ± 0.7 | 2.6 ± 0.8 |

*continued*

**Table 3. Continued**

| Item | Response[b] | Group[a] Low | Mod | High | Total |
|---|---|---|---|---|---|
| 9. Drinking sport beverages with carbohydrates and electrolytes before or during exercise can improve performance during runs of *less than 1 hour* compared to water. | Strongly disagree, % | 9 | 13 | 7 | 9 |
| | Disagree, % | 37 | 40 | 44 | 40 |
| | Agree, % | 30 | 32 | 29 | 30 |
| | Strongly agree, % | 4 | 1 | 1 | 2 |
| | Not applicable/do not know, % | 20 | 14 | 20 | 18 |
| | Mean ± SD | 2.4 ± 0.8 | 2.2 ± 0.7 | 2.3 ± 0.6 | 2.3 ± 0.7 |
| 10. Drinking sport beverages with carbohydrates and electrolytes before or during exercise can improve performance for runs of *greater than 1 hour* compared to water. | Strongly disagree, % | 3 | 3 | 0 | 2 |
| | Disagree, % | 10 | 19 | 7 | 12 |
| | Agree, % | 49 | 52 | 45 | 49 |
| | Strongly agree, % | 19 | 20 | 41 | 26 |
| | Not applicable/do not know, % | 20 | 7 | 8 | 11 |
| | Mean ± SD | 3.0 ± 0.7[c] | 2.9 ± 0.7[c] | 3.4 ± 0.6 | 3.1 ± 0.6 |

[a] Low, Mod, and High are tertile classifications based on training volume, expected performance, and running experience.

[b] 1, *strongly disagree;* 2, *disagree;* 3, *agree;* 4, *strongly agree.*

[c] Different from High ($P < .05$).

*disagree*, *disagree*, *agree*, *strongly agree*, and *not applicable or do not know*.

Participants were also asked whether they had ever experienced heat-related illness symptoms or a major decrease in running performance that they believed was caused by dehydration, with response choices of *yes (once), yes (more than once), no,* or *do not know* (Table 4).

In the final section, participants were asked whether they used any method to monitor their hydration status, followed by an open-ended response section to list any monitoring methods used. The final question asked participants whether they drank during their outdoor runs in warm or hot environments. Response choices were *never, sometimes, very often,* or *always*. This question was followed by an open-ended section for participants to describe how they supplied themselves with fluids during runs.

## Data Analyses

Quantitative data values are presented as mean ± standard deviation for continuous variables or as frequencies by percentages for nominal variables. One-way analysis of variance was used to determine whether differences existed in VPE for demographic and visual analog scale responses. For items in Table 3, categorical responses were converted as follows: *strongly disagree* = 1, *disagree* = 2, *agree* = 3, and *strongly agree* = 4. *Not*

**Table 4. Incidence of Decreased Performance and Heat Illness Related to Inadequate Hydration (N = 276)**

| Item | Response[b] | Group[a] Low | Mod | High | Total |
|---|---|---|---|---|---|
| 1. Have you ever experienced a major decrease in running performance that you feel was caused from being dehydrated? | No, % | 36 | 27 | 17 | 27 |
| | Once, % | 29 | 26 | 21 | 25 |
| | More than once, % | 33 | 41 | 59 | 44 |
| | Do not know, % | 2 | 5 | 3 | 4 |
| | Mean ± SD | 2.0 ± 0.8[c] | 2.1 ± 0.8 | 2.4 ± 0.8 | 2.2 ± 0.8 |
| 2. Have you ever suffered heat-related illness symptoms (severe muscle or stomach cramping, light-headedness, dizziness, nausea, or loss of ability to think clearly) while running that you feel were caused from being dehydrated? | No, % | 58 | 62 | 45 | 55 |
| | Once, % | 21 | 16 | 28 | 22 |
| | More than once, % | 21 | 21 | 26 | 23 |
| | Do not know, % | 1 | 1 | 0 | 1 |
| | Mean ± SD | 1.6 ± 0.8 | 1.6 ± 0.8 | 1.8 ± 0.8 | 1.7 ± 0.8 |

[a] Low, Mod, and High are tertile classifications based on training volume, expected performance, and running experience.

[b] 1, *no;* 2, *once;* 3, *more than once.*

[c] Different from High ($P = .001$).

*applicable or do not know* responses were removed from comparisons. Categorical response items in Table 4 were converted as follows: *yes (more than once)* = 3, *yes (once)* = 2, and *no* = 1. A 1-way analysis of variance was also used to analyze differences among VPE level groups for these items, and Tukey post hoc tests were calculated when omnibus effects were found for VPE level. Responses for the visual analog scale item that addressed the use of sport beverages and items (Tables 3 and 4) were also compared between participants registered to run the half-marathon and full marathon and between men and women runners using independent-samples *t* tests. Open-ended responses were evaluated and placed into categories determined by members of the investigation team. An alpha level of .05 was used for all hypothesis tests.

## RESULTS

Fifty-five percent (n = 80) of male runners and 29% (n = 38) of female runners who completed the survey were registered to run the full marathon. Participants' training histories, the race for which they registered, and expected finish time by VPE level and for the total sample are detailed in Table 1. Differences in VPE level were noted for all continuous variables (miles per week, number of competitions of half-marathon distance or longer, years of running experience of half-marathon distance or longer, and aerobic exercise sessions per week: $P < .001$) and for predicted finishing time. Differences were observed between the Low and High groups for all continuous variables ($P < .001$) and between the Low and Mod groups for all continuous variables ($P < .001$) except the number of running competitions of half-marathon distance or longer in the last 2 years and number of exercise sessions per week lasting longer than 1 hour ($P > .05$).

Advice from other runners about exercise beverage choices and hydration was reported as the greatest source of influence (major influence = 64%, n = 177) by participants. Complete results for sources of influence on hydration strategies are displayed in Table 2.

The High group reported greater regular consumption of sport beverages in exercise environments than did the Low ($P < .001$) or Mod ($P < .001$) groups (Table 1). The Low and Mod groups reported less agreement than did the High group with the statement "Sport beverages are superior to water in meeting hydration needs of exercisers" ($P = .01$; Table 3). Participants in the Mod group were more likely to strongly agree with the statement "I prefer the taste of water over sport beverages in exercise environments" than did those in the High group ($P = .03$). A total of 31% (n = 86) of runners agreed with the statement that they avoided drinking sport beverages because of their caloric content, and 50% (n = 138) drank low-calorie or noncaloric sport beverages. Thirty-eight percent of runners (n = 105) reported drinking high-carbohydrate beverages or carbohydrate and protein beverages. Those in the Mod group reported less agreement than did those in the High group with "Drinking a sport beverage instead of water will result in better recovery and improved performance for my next exercise session" ($P = .02$). Compared with the Low and Mod groups, the High group was more likely to agree that "Drinking sport beverages with carbohydrates and electrolytes before or during exercise can improve performance for runs of greater than 1 hour compared to water" ($P < .01$). Results by VPE and total responses for the items discussed above based on VPE are presented in Table 3.

Almost 70% of participants (n = 190) believed that they had experienced a major decrease in performance (and 44% [n = 121] reported multiple incidents) due to dehydration (Table 4). The High group reported more performance decrements than did the Low group ($P = .001$), and differences between the High and Mod groups approached significance ($P = .07$). Fifty-four percent of the High group (n = 50) reported suffering from heat-related illness symptoms they believed were caused by dehydration during a run, compared with 42% (n = 39) for the Low and 37% (n = 34) for the Mod group, but no differences were found among VPE levels.

Twenty percent of runners (n = 55) reported monitoring hydration status (Table 5). Urine color was the most often reported method (7%, 20 runners). Although not technically a method for measuring hydration status, predetermining the amount or time intervals (or both) that they would drink during the run was cited by 9 runners (3%). Nine participants (3%) also listed frequency or volume of urination as a marker of hydration, followed by 8 runners (3%) who reported using thirst or "listening to [their] body" as a guide. Only 5 participants (2%) listed measuring changes in body weight as a method they used.

A total of 42% of runners (n = 117) reported always drinking during their outdoor runs in warm or hot environments, whereas 6% (n = 16) reported never drinking during outdoor runs in warm or hot environments (Table 6). Carrying bottles in their hands or in a waist belt or using a backpack-type hydration system was the most commonly reported means of obtaining fluid during a run (62%, n = 170), followed by placing bottles on the route before the run (21%, n = 58) and drinking from public water fountains or faucets (12%, n = 32).

Full-marathon runners reported greater (56 ± 30 mm) regular consumption of sport beverages in exercise environments than did half-marathon runners (39 ± 34, $P < .001$), but no difference between sexes was found (men = 48 ± 33, women = 45 ± 35, $P > .05$). Women reported greater agreement (3.3 ± 0.7) than did men (3.1 ± 0.7, $P = .02$) with the concept of intentionally increasing fluid consumption outside of exercise environments during warm or hot weather (Table 3, item 1). Stronger agreement was reported by full-marathon (2.8 ± 0.8) than half-marathon (2.6 ± 0.8, $P = .02$) runners with the statement, "Sport beverages are superior to water in meeting hydration needs of exercisers" (Table 3, item 2). Differences in agreement about a preference for the taste of water over sport beverages in exercise environments were found by both sex (men = 2.6 ± 0.8, women = 2.9 ± 1.0, $P = .02$) and distance of race registered to run (half-marathon = 2.9 ± 0.9, full marathon = 2.5 ± 0.9, $P < .01$) (Table 3, item 3). In comparison with men (2.0 ± 0.9) and full-marathon runners (2.0 ± 0.8), women (2.4 ± 1.0) and half-marathon runners (2.4 ± 1.0) reported greater agreement (both $P < .01$) with the statement that they avoided sport beverages because of their caloric content (Table 3, item 4). Half-marathon runners reported greater consumption of low-calorie or zero-calorie sport beverages than did full-marathon runners (2.7 ± 1.0 and 2.3 ± 1.1, respectively; $P < .01$) (Table 3, item 6). No differences were seen between male and female runners or between half-marathon and full-marathon runners for any other items. Complete results based on these variables are exhibited in Appendices A–D.

## DISCUSSION

Dehydration during strenuous physical activity, particularly in warm or hot environments, can increase the risk of heat

**Table 5. Hydration Monitoring and Methods Used (n = 276)**

| Item | Response | Group[a] | | | |
|---|---|---|---|---|---|
| | | Low | Mod | High | Total |
| Do you use any method to monitor your hydration status? % | Yes | 15 | 21 | 23 | 20 |
| | No | 80 | 71 | 73 | 74 |
| | Do not know | 4 | 9 | 4 | 6 |
| Methods used, No. | | | | | |
| Urine color | | 6 | 7 | 7 | 20 |
| Preplanning amount of fluid to be consumed or intervals at which to drink | | 3 | 3 | 3 | 9 |
| Frequency or volume of urination | | 3 | 4 | 2 | 9 |
| Thirst and listening to body | | 2 | 2 | 4 | 8 |
| Dehydration-induced symptoms (eg, "lack of sweating," "calf cramps," dry skin, chapped lips, "hand moisture") | | 1 | 3 | 3 | 7 |
| Sweat rate | | 0 | 2 | 4 | 6 |
| Skin turgor test | | 3 | 1 | 1 | 5 |
| Change in body weight | | 0 | 1 | 4 | 5 |
| Total body water measurement predictor tool | | 0 | 1 | 1 | 2 |
| Total | | 18 | 24 | 29 | 71 |

[a] Low, Mod, and High are tertile classifications based on training volume, expected performance, and running experience.

exhaustion, heat stroke, and muscle cramping.[5,6,13] Although the finding is still debated by some,[17] dehydration of more than 2% of body weight has been shown to result in reduced aerobic performance capacity for many people.[5,18–20] The scientific community has devoted much attention to the type, quantity, and timing of fluid athletes should consume. As the popularity of distance running increases, a growing population may face the negative performance or health consequences of inadequate hydration strategies. In this investigation, we explored the practices and perceptions of runners regarding hydration and exercise environment beverage choice.

Our most important finding was the large number of runners who believed that performance decrements and heat-related illness symptoms were caused by inadequate fluid intake. Decreases in running performance thought to have been caused by dehydration were common (70% of participants), and the incidence rate increased with VPE level (Table 4). This outcome may be attributable to the increased distances, frequencies, and intensity levels of runs undertaken by those in the higher VPE levels. Even though we provided no definition for "major decrease in running performance," and response rates were based on participants' subjective interpretations, it is nonetheless apparent that the majority of runners believed they had experienced decreased performance because of inadequate fluid intake. Future investigations concerning why athletes reached a point of dehydration that resulted in decreased performance (eg, inadequate intake before or during the run, lack of fluid availability, inadequate prerun hydration strategy to compensate for actual fluid deficit, unexpected change in weather) are warranted.

**Table 6. Reported Fluid Intake Habits During Outdoor Runs and Methods of Fluid Delivery**

| Item, % | Response | Group[a] | | | |
|---|---|---|---|---|---|
| | | Low | Mod | High | Total (n = 275[b]) |
| Do you drink during your outdoor runs in warm or hot environments? | Never | 10 | 4 | 3 | 6 |
| | Sometimes | 22 | 30 | 19 | 24 |
| | Very often | 27 | 24 | 33 | 28 |
| | Always | 40 | 41 | 46 | 42 |
| Running belt with fluid bottles, carry bottle in hand, backpack hydration system | | 49 | 60 | 61 | 170 |
| Place bottles on route prior to run | | 13 | 24 | 21 | 58 |
| Drink from public fountains or faucets | | 8 | 5 | 19 | 32 |
| Have someone bring fluids to runner during run | | 4 | 7 | 6 | 17 |
| Run loops past home or car with prepared fluids | | 4 | 1 | 3 | 8 |
| Purchase beverages at stores along running route | | 2 | 1 | 3 | 6 |
| Total[c] | | 80 | 98 | 113 | 291 |

[a] Low, Mod, and High are tertile classifications based on training volume, expected performance, and running experience.

[b] One runner in the Low group did not respond to this question.

[c] Runners could report more than 1 method of fluid delivery.

Forty-five percent of participants reported they had suffered heat-related illness symptoms that they thought were caused by dehydration. The relationship among environmental conditions, intensity of physical activity, and fluid intake in heat illness is complex, and individual athletes may have different responses to similar conditions. However, dehydration is believed to exacerbate the symptoms of heat-related illness, and fluid intake is a preventive measure suggested by the American College of Sports Medicine[13] and the National Athletic Trainers' Association.[15] Our results indicate that most runners agreed that hydration during runs in the heat is particularly important and reported that they take frequent steps to make sure they can access fluids during runs by a variety of means. Whether this impetus comes from personal negative experiences or trusting in the advice given by a variety of influential sources is unknown. Regardless of the reason, at some point the majority of these runners thought that inadequate fluid intake had led to less than optimal performance, and nearly half believed that dehydration had resulted in health impairment during a run.

Winger et al[21] found that runners relied most heavily on their own experiences when developing hydration strategies. We considered only external sources of influence. However, in agreement with Winger et al,[21] interpersonal contacts (particularly with other runners) rather than information provided through peer-reviewed literature, professional association position stands, or advertisements (Table 2) were the primary sources of information about hydration strategies and exercise-related beverage choices. These findings highlight the fact that for health care professionals to reach the largest audience, information about hydration and fueling for performance and safety must be disseminated in a conversational format. Information disseminated on a more personal level may be perceived as more trustworthy.

Most runners (89%) trained without supervision. Therefore, it is important for health care professionals to interact with people in the running community who are likely to pass the information on to other runners. Speaking to local running clubs and setting up information booths at prerace running expositions are excellent opportunities to distribute information on a more personal level that can be passed on to other running community members through word of mouth.

The High group reported greater use of sport beverages in exercise environments than did the Low and Mod groups. Beliefs about rehydration properties and ergogenic effects of sport beverages may account for these differences. The High group reported greater levels of agreement with the statements "Sport beverages are superior to water in meeting the hydration needs of exercisers" and "Drinking sport beverages with carbohydrates and electrolytes before or during exercise can improve performance for runs of greater than 1 hour compared to water" than did the Low and Mod groups. Experienced endurance athletes drink more sport beverage (even when a least-liked flavor is given) than water during prolonged exercise when both beverages are continuously available[22] and when drinking opportunities are limited.[23] The High group's greater level of agreement with "Drinking sport beverages with carbohydrates and electrolytes before or during exercise can improve performance for runs of greater than 1 hour compared to water" is supported by scientific evidence.[16,24] The differences among these groups could be a result of the High group's running longer distances at greater intensities, their past experiences, or their greater exposure to information supporting the use of carbohydrate beverages. The belief that carbohydrate-containing beverages will improve performance has also been noted in highly trained endurance athletes. Clark et al[25] found lower levels of improvement in a subsequent time trial when a group of highly trained cyclists was misled into believing they were drinking a noncalorically sweetened sports drink and actually given a carbohydrate sport beverage than in another group given a placebo and told they were receiving a carbohydrate sport beverage. Also, half-marathon runners and women reported greater agreement than other runners in avoiding sport beverages because of their caloric content. Beliefs about the effect of beverage choice on weight management are important factors for many runners, so low-calorie or no-calorie flavored sport beverage options may be useful for promoting fluid replacement.

Runners often have a heightened sense of focus on nutrition and hydration in the days leading up to a race and are likely to begin a competition in a hyperhydrated or euhydrated state. However, a state of adequate hydration may not be the case during training, when runs are frequently scheduled around work and other activities. When fluid may not be readily available (as opposed to during a race with hydration stations), a key aspect of hydration is pre-exercise hydration status.[5,13,14] Urine color was the most reported method (20 runners) used to assess hydration status. This simple technique correlates highly with urine specific gravity and urine osmolality[26] and is a practice supported by the National Athletic Trainers Association.[6]

When asked whether they monitored their hydration status, a few participants in our survey reported a specific hydration plan (eg, "Measure out water"; "I just rehydrate every 20–30 minutes in cold runs—every 10–15 minutes in hot weather"; "Drink fluid on my belt and, depending on weather, drink every 2 miles"). How runners determined the quantity of fluids and when they should consume fluids is unknown. Six runners (2%) listed a method involving sweat rate. Responses ranged from specific strategies (eg, "Sweat rate, lots of sweat—more intake—up to a point; I replace no more than half that I lose") to indistinct observations (eg, "How wet my clothes are"). No runners reported how they assessed sweat rate.

Measuring changes in body mass is the most accurate way to determine acute changes in hydration level and sweat loss[27] and is a vital component for developing an individual hydration strategy.[13,14] However, only 5 (4 of these from the High group) of 276 runners (2%) reported measuring changes in body weight. Runners tend to greatly underestimate their actual sweat losses.[11] Ambiguity in open-ended responses about changes in body weight makes it difficult to assess whether runners were referring to acute or daily changes in body mass. This hydration monitoring technique can be implemented by any runner with an accurate scale and should be more heavily promoted. Eight runners (3%) listed thirst or "listening to [my] body." Unfortunately, we did not ask whether these responses were based on the International Marathon Medical Directors Association[8] recommendations.

Much effort has been undertaken to develop hydration guidelines for athletes, but the experiences and viewpoints of runners themselves are not well understood. Runners' beverage choices (eg, higher-volume runners reported greater sport beverage consumption) reflected current recommendations. Yet developing and actively monitoring individualized fluid-intake strategies based on the consensus of guidelines[5,6] do not appear to be common practices for most participants, despite many reports of negative sequelae related to dehydration. Because

almost all participants served as their own coaches, they should be encouraged to measure body weight changes during exercise to develop individual hydration plans. This is a simple method that appears to be underused and should be better promoted in the running community.

A limitation of this study was that 70% of participants resided in regions of the United States where hot and humid conditions are common during much of the year. Runners training in more arid and cooler regions may have different opinions and experiences regarding hydration needs and habits. Similarly, the results from this sample of predominantly recreational runners who did not train under the supervision of experienced coaching and training staffs are not intended to be extrapolated to more elite-level distance runners.

Upon completing this survey, numerous participants shared personal stories with the investigators about negative experiences with running and dehydration. Their ideas on the proper way to stay hydrated varied greatly. Many runners had firmly entrenched beliefs about what, how much, and when they should drink. However, many were unsure about their hydration habits and were interested in our personal views on what they should be doing. Future investigators should explore how scientific findings and position stands published in peer-reviewed journals can be better disseminated to the public.

**Appendix A. Runners' Beverage Choices and Perceptions of Differences Between Water and Sport Beverages**

| | | Race | | Sex | |
|---|---|---|---|---|---|
| Item | Response[a] | Half-Marathon (n = 158) | Full Marathon (n = 118) | Men (n = 146) | Women (n = 130) |
| 1. I intentionally increase the volumes of fluids I drink in non-exercise environments during periods of warm or hot weather. | Strongly disagree, % | 3 | 4 | 4 | 3 |
| | Disagree, % | 9 | 7 | 10 | 5 |
| | Agree, % | 52 | 60 | 59 | 52 |
| | Strongly agree, % | 36 | 28 | 27 | 40 |
| | Not applicable/do not know, % | 7 | 2 | 3 | 6 |
| | Mean ± SD | 3.2 ± 0.7 | 3.1 ± 0.7 | 3.1 ± 0.7[b] | 3.3 ± 0.7 |
| 2. Sport beverages are superior to water in meeting hydration needs of exercisers. | Strongly disagree, % | 8 | 4 | 4 | 9 |
| | Disagree, % | 37 | 30 | 34 | 33 |
| | Agree, % | 45 | 44 | 46 | 42 |
| | Strongly agree, % | 11 | 22 | 16 | 16 |
| | Not applicable/do not know, % | 19 | 5 | 6 | 18 |
| | Mean ± SD | 2.6 ± 0.8[c] | 2.8 ± 0.8 | 2.7 ± 0.8 | 2.7 ± 0.9 |
| 3. I prefer the taste of water over sport beverages in exercise environments. | Strongly disagree, % | 7 | 1 | 6 | 9 |
| | Disagree, % | 27 | 40 | 39 | 26 |
| | Agree, % | 34 | 34 | 40 | 28 |
| | Strongly agree, % | 32 | 15 | 15 | 35 |
| | Not applicable/do not know, % | 7 | 4 | 5 | 6 |
| | Mean ± SD | 2.9 ± 0.9[d] | 2.5 ± 0.9 | 2.6 ± 0.8[b] | 2.9 ± 1.0 |
| 4. I avoid drinking sport beverages because of their caloric content. | Strongly disagree, %[b] | 19 | 32 | 29 | 19 |
| | Disagree, % | 43 | 43 | 47 | 38 |
| | Agree, % | 23 | 24 | 18 | 29 |
| | Strongly agree, % | 16 | 2 | 6 | 14 |
| | Not applicable/do not know, % | 12 | 5 | 7 | 10 |
| | Mean ± SD | 2.4 ± 1.0[d] | 2.0 ± 0.8 | 2.0 ± 0.9[e] | 2.4 ± 1.0 |
| 5. I dilute regular sport beverages with water. | Strongly disagree, % | 28 | 33 | 32 | 28 |
| | Disagree, % | 26 | 27 | 29 | 23 |
| | Agree, % | 25 | 20 | 18 | 29 |
| | Strongly agree, % | 20 | 20 | 20 | 20 |
| | Not applicable/do not know, % | 24 | 8 | 10 | 22 |
| | Mean ± SD | 2.4 ± 1.1 | 2.3 ± 1.1 | 2.3 ± 1.1 | 2.4 ± 1.1 |
| 6. I drink low- or zero-calorie sport beverages. | Strongly disagree, % | 15 | 32 | 24 | 20 |
| | Disagree, % | 25 | 21 | 26 | 22 |
| | Agree, % | 41 | 33 | 37 | 37 |
| | Strongly agree, % | 20 | 15 | 14 | 22 |
| | Not applicable/do not know, % | 15 | 8 | 9 | 14 |
| | Mean ± SD | 2.7 ± 1.0[d] | 2.3 ± 1.1 | 2.4 ± 1.0 | 2.6 ± 1.0 |
| 7. I drink beverages marketed as "recovery" beverages that contain high percentages of carbohydrates or a carbohydrate and protein combination. | Strongly disagree, % | 24 | 19 | 20 | 24 |
| | Disagree, % | 34 | 36 | 32 | 37 |
| | Agree, % | 33 | 35 | 35 | 33 |
| | Strongly agree, % | 10 | 10 | 13 | 6 |
| | Not applicable/do not know, % | 18 | 18 | 19 | 17 |
| | Mean ± SD | 2.3 ± 0.9 | 2.4 ± 0.9 | 2.4 ± 1.0 | 2.2 ± 0.9 |
| 8. Drinking a sport beverage instead of water after exercise will result in better recovery and improved performance for my next exercise session. | Strongly disagree, % | 9 | 7 | 6 | 9 |
| | Disagree, % | 35 | 30 | 35 | 29 |
| | Agree, % | 47 | 48 | 44 | 51 |
| | Strongly agree, % | 9 | 16 | 14 | 10 |
| | Not applicable/do not know, % | 30 | 13 | 19 | 24 |
| | Mean ± SD | 2.6 ± 0.8 | 2.7 ± 0.8 | 2.7 ± 0.8 | 2.6 ± 0.8 |

*(continued)*

**Appendix A. Continued**

| Item | Response[a] | Race | | Sex | |
|---|---|---|---|---|---|
| | | Half-Marathon (n=158) | Full Marathon (n=118) | Men (n=146) | Women (n=130) |
| 9. Drinking sport beverages with carbohydrates and electrolytes before or during exercise can improve performance during runs of less than 1 hour compared to water. | Strongly disagree, % | 10 | 14 | 13 | 10 |
| | Disagree, % | 52 | 45 | 43 | 56 |
| | Agree, % | 36 | 39 | 40 | 33 |
| | Strongly agree, % | 2 | 3 | 4 | 1 |
| | Not applicable/do not know, % | 34 | 15 | 24 | 25 |
| | Mean±SD | 2.3±0.7 | 2.3±0.7 | 2.4±0.8 | 2.3±0.6 |
| 10. Drinking sport beverages with carbohydrates and electrolytes before or during exercise can improve performance for runs of greater than 1 hour compared to water. | Strongly disagree, % | 2 | 3 | 2 | 3 |
| | Disagree, % | 16 | 10 | 13 | 13 |
| | Agree, % | 55 | 54 | 50 | 60 |
| | Strongly agree, % | 26 | 34 | 34 | 25 |
| | Not applicable/do not know, % | 28 | 3 | 11 | 20 |
| | Mean±SD | 3.1±0.7 | 3.2±0.7 | 3.2±0.7 | 3.1±0.7 |

[a] 1, *strongly disagree;* 2, *disagree;* 3, *agree;* 4, *strongly agree*. Percentages and differences between groups were calculated excluding *not applicable* and *do not know* responses.

[b] Different from women ($P<.05$).

[c] Different from full marathon ($P<.05$).

[d] Different from full marathon ($P<.01$).

[e] Different from women ($P<.01$).

**Appendix B. Incidence of Decreased Performance and Heat Illness Related to Inadequate Hydration (N=276)**

| Item | Response[a] | Race | | Sex | |
|---|---|---|---|---|---|
| | | Half-Marathon (n=158) | Full Marathon (n=118) | Men (n=146) | Women (n=130) |
| 1. Have you ever experienced a major decrease in running performance that you feel was caused from being dehydrated? | No, % | 30 | 24 | 27 | 29 |
| | Once, % | 32 | 18 | 19 | 35 |
| | More than once, % | 37 | 58 | 54 | 37 |
| | Do not know, % | 3 | 7 | 6 | 4 |
| | Mean±SD | 2.0±0.8 | 2.1±0.7 | 2.1±0.7 | 1.9±0.8 |
| 2. Have you ever suffered heat-related illness symptoms during a run (severe muscle or stomach cramping, light-headedness, dizziness, nausea, or loss of ability to think clearly) while running that you feel were caused from being dehydrated? | No, % | 60 | 50 | 56 | 56 |
| | Once, % | 21 | 23 | 24 | 19 |
| | More than once, % | 19 | 28 | 20 | 26 |
| | Do not know, % | 2 | 1 | 2 | 1 |
| | Mean±SD | 2.4±0.8 | 2.3±0.8 | 2.3±0.8 | 2.4±0.8 |

[a] 1, *no;* 2, *once;* 3, *more than once*. Percentages were calculated excluding do not know responses.

**Appendix C. Participants Reporting Hydration Monitoring (N=276)**

| Item | Response | Race | | Sex | |
|---|---|---|---|---|---|
| | | Half-Marathon (n=158) | Full Marathon (n=118) | Men (n=146) | Women (n=130) |
| Do you use any method to monitor your hydration status? % | Yes | 18 | 21 | 20 | 20 |
| | No | 76 | 73 | 74 | 76 |
| | Do not know | 6 | 6 | 6 | 5 |

**Appendix D. Runners' Reported Fluid Intake Habits During Outdoor Runs and Methods of Fluid Delivery (N = 276)**

| Item | Response | Race | | Sex | |
|---|---|---|---|---|---|
| | | Half-Marathon (n = 158) | Full Marathon (n = 118) | Men (n = 146) | Women (n = 130) |
| Do you drink during your outdoor runs in warm or hot environments? % | Never | 9 | 2 | 6 | 6 |
| | Sometimes | 30 | 15 | 27 | 20 |
| | Very often | 24 | 34 | 28 | 28 |
| | Always | 38 | 49 | 40 | 46 |

## REFERENCES


1. USA Marathon. 2009 overview. http://www.marathonguide.com/Features/Articles/2009RecapOverview.cfm. Accessed April 10, 2010.
2. 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.
3. Convertino VA, Armstrong LE, Coyle EF, et al. American College of Sports Medicine position stand: exercise and fluid replacement. *Med Sci Sports Exerc*. 1996;28(1):i–vii.
4. Noakes TD. Drinking guidelines for exercise: what evidence is there that athletes should drink "as much as tolerable," "to replace the weight lost during exercise" or "ad libitum"? *J Sports Sci*. 2007;25(7):781–796.
5. American College of Sports Medicine, Sawka MN, Burke LM, et al. American College of Sports Medicine position stand: exercise and fluid replacement. *Med Sci Sports Exerc*. 2007;39(2):377–390.
6. Casa DJ, Armstrong LE, Hillman SK, et al. National Athletic Trainers' Association position statement: fluid replacement for athletes. *J Athl Train*. 2000;35(2):212–224.
7. Rodriguez NR, DiMarco NM, Langley S, American Dietetic Association, Dietitians of Canada, American College of Sports Medicine. Position of the American Dietetic Association, Dietitians of Canada, and the American College of Sports Medicine: nutrition and athletic performance. *J Am Diet Assoc*. 2009;109(3):509–527.
8. Hew-Butler T, Verbalis JG, Noakes TD, International Marathon Medical Directors Association. Updated fluid recommendation: position statement from the International Marathon Medical Directors Association (IMMDA). *Clin J Sport Med*. 2006;16(4):283–292.
9. Almond CS, Shin AY, Fortescue EB, et al. Hyponatremia among runners in the Boston Marathon. *N Engl J Med*. 2005;352(15):1550–1556.
10. Shendell DG, Alexander MS, Lorentzson L, McCarty FA. Knowledge and awareness of heat-related morbidity among adult recreational endurance athletes. *Int J Biometeorol*. 2010;54(4):441–448.
11. Passe D, Horn M, Stofan J, Horswill C, Murray R. Voluntary dehydration in runners despite favorable conditions for fluid intake. *Int J Sport Nutr Exerc Metab*. 2007;17(3):284–295.
12. Grandjean AC, Grandjean NR. Dehydration and cognitive performance. *J Am Coll Nutr*. 2007;26(5 suppl):549S–554S.
13. Armstrong LE, Casa DJ, Millard-Stafford M, Moran DS, Pyne SW, Roberts WO. American College of Sports Medicine position stand: exertional heat illness during training and competition. *Med Sci Sports Exerc*. 2007;39(3):556–572.
14. Maughan RJ, Shirreffs SM. Development of individual hydration strategies for athletes. *Int J Sport Nutr Exerc Metab*. 2008;18(5):457–472.
15. Binkley HM, Beckett J, Casa DJ, Kleiner DM, Plummer PE. National Athletic Trainers' Association position statement: exertional heat illnesses. *J Athl Train*. 2002;37(3):329–343.
16. Coyle EF. Fluid and fuel intake during exercise. *J Sports Sci*. 2004;22(1):39–55.
17. Sawka MN, Noakes TD. Does dehydration impair exercise performance? *Med Sci Sports Exerc*. 2007;39(8):1209–1217.
18. Armstrong LE, Costill DL, Fink WJ. Influence of diuretic-induced dehydration on competitive running performance. *Med Sci Sports Exerc*. 1985;17(4):456–461.
19. Below PR, Mora-Rodriguez R, Gonzalez-Alonso J, Coyle EF. Fluid and carbohydrate ingestion independently improve performance during 1 h of intense exercise. *Med Sci Sports Exerc*. 1995;27(2):200–210.
20. Fallowfield JL, Williams C, Booth J, Choo BH, Growns S. Effect of water ingestion on endurance capacity during prolonged running. *J Sports Sci*. 1996;14(6):497–502.
21. 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.
22. Passe DH, Horn M, Murray R. Impact of beverage acceptability on fluid intake during exercise. *Appetite*. 2000;35(3):219–229.
23. Passe DH, Horn M, Stofan J, Murray R. Palatability and voluntary intake of sports beverages, diluted orange juice, and water during exercise. *Int J Sport Nutr Exerc Metab*. 2004;14(3):272–284.
24. Jeukendrup AE. Carbohydrate intake during exercise and performance. *Nutrition*. 2004;20(7–8):669–677.
25. Clark VR, Hopkins WG, Hawley JA, Burke LM. Placebo effect of carbohydrate feedings during a 40-km cycling time trial. *Med Sci Sports Exerc*. 2000;32(9):1642–1647.
26. Armstrong LE, Soto JA, Hacker FT Jr, Casa DJ, Kavouras SA, Maresh CM. Urinary indices during dehydration, exercise, and rehydration. *Int J Sport Nutr*. 1998;8(4):345–355.
27. Armstrong LE. Assessing hydration status: the elusive gold standard. *J Am Coll Nutr*. 2007;26(5 suppl):575S–584S.


*Address correspondence to Eric K. O'Neal, PhD, 1 Harrison Plaza, UNA Box 5073, Florence, AL 35632. Address e-mail to eoneal1@una.edu.*