Hydration Strategies, Weight Change and Performance in a 161 km Ultramarathon

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To examine controversies about hydration strategies, participants (383 starters) of a 161 km ultramarathon (maximum temperature 39.0°C) underwent body weight measurements before, during and after the race; and completed a post-race questionnaire on drinking strategies and sodium supplementation use during 4 race segments. Drinking to thirst was the most common (p < 0.01) drinking strategy (used by 67.0% during at least one segment) and most runners (95.6%) used sodium supplementation during at least one segment. There was no difference in the extent of weight loss (mean 2.0–3.1%) or the weight change pattern when comparing groups using different hydration strategies. Among top-10 finishers, half had lost more than 2% of starting body weight by 90 km. We conclude that weight loss greater than 2% does not necessarily have adverse consequences on performance, and use of sodium supplements or drinking beyond thirst is not required to...
maintain hydration during ultra-endurance events with high thermal stress.

KEYWORDS dehydration, endurance exercise, exercise, sodium, water-electrolyte imbalance

Recent guidelines advise individuals performing physical activity to ingest sodium and to consume enough fluids to avoid more than 2% loss in body weight during exercise (American College of Sports Medicine et al., 2007; Casa et al., 2000; Casa, Clarkson, & Roberts, 2005; Lipman et al., 2013). The premise for these recommendations is that exercise performance will deteriorate with over 2% body weight loss and that electrolyte consumption can help sustain fluid electrolyte balance. However, prior work has demonstrated that top performers in endurance events often finish with body weight losses well over 3–4% (Hoffman, Hew-Butler, & Stuempfle, 2013a; Kao et al., 2008; Sharwood, Collins, Goedecke, Wilson, & Noakes, 2002, 2004; Wharam et al., 2006; Zouhal et al., 2011). Conventional thinking suggests that such levels of weight loss should impair performance, even when recognizing that ~1% body weight loss could be from fat utilization in events as long as a 161 km ultramarathon (Stuempfle et al., 2011).

The recommendations on sodium ingestion during exercise can also be challenged. Some studies have shown that supplemental sodium during prolonged exercise has little or no effect on maintenance of body weight (Cosgrove & Black, 2013; Hew-Butler, Sharwood, Collins, Speedy, & Noakes, 2006; Speedy et al., 2002), does not affect post-race blood sodium concentration (Cosgrove & Black, 2013; Hew-Butler et al., 2006; Speedy et al., 2002; Winger et al., 2013), and does not prevent hyponatremia when the athlete is overhydrating (Twerenbold et al., 2003). Excessive sodium may even increase the risk for development of pulmonary edema during exercise (Luks, Robertson, & Swenson, 2007). Therefore, the recommendations to ingest sodium and to drink to avoid more than 2% body weight loss are not universally supported by the scientific literature. Recommendations to avoid excessive sodium supplementation and to drink to thirst have been suggested as being most appropriate during endurance exercise (Bennett, Hew-Butler, Hoffman, Rogers, & Rosner, 2013; Rosner, Bennett, Hew-Butler, & Hoffman, 2013).

It is worth noting that little is known about how weight changes across intermediate sections of endurance events (Kao et al., 2008). In top performers with weight loss beyond 2%, it is conceivable that the majority of weight loss occurs in the final stages of the event. Since there has generally been a lack of weight change data at intermediate locations during endurance events, it is also not clear if weight change might be a factor in determining who fails to finish.

Given the controversies about hydration and sodium supplementation during exercise and lack of information about weight change during events, further investigation is warranted into the impact of drinking and sodium
supplementation strategies on weight change during an ultra-endurance event as well as the influence of weight change on performance. Thus, the purpose of this study was to measure body weight at intervals throughout a 161 km ultramarathon in order to (1) determine whether strategies relative to drinking and use of sodium supplements affect weight change during the event; (2) examine if weight change is a determining factor for whether a runner finishes or not; and (3) explore whether the majority of weight loss among those top performers losing more than 2% body weight might be in the final stages of the event.

METHODS

The study was performed at the 2013 Western States Endurance Run (WSER), a 161.3 km ultramarathon through the Sierra Nevada Mountains of northern California. Details of this race have been provided elsewhere (Hoffman & Fogard, 2011; Hoffman, Ingwerson, Rogers, Stuempfle, & Hew-Butler, 2012; Hoffman, Stuempfle, Rogers, Weschler, & Hew-Butler, 2011; Hoffman & Wegelin, 2009; Parise & Hoffman, 2011; Rogers, Hook, Stuempfle, Hoffman, & Hew-Butler, 2011). The 2013 WSER had exceptionally hot ambient temperature conditions (reported as the second hottest year) with nearby temperatures during the competition ranging from a low of 5.0°C just after the start to 39.0°C in the afternoon. Relative humidity during the hottest portion of the race was 18–36% and wind speed remained below 15 km h⁻¹ throughout the event. The research was approved by our institutional review boards with waiver of consent for the weight measurements and electronic consent obtained from those participating in the questionnaire portion of the study.

Race starters underwent body weight measurement at race registration (in the morning the day before the race), within 1.5 hours of the start of the race, when reaching 47.8 km, 89.6 km and 125.5 km during the race, and again immediately after finishing the race. Each measurement was made with the runner clothed in running wear and shoes, but other items such as waist packs and hydration vests were removed, and nothing was permitted in the runner’s hands. All weight measurements were made with calibrated scales (Health o meter, model 349KLX, Bridgeview, IL, USA) that were on firm surfaces confirmed to be level by measurement. Prior to the event, the scales were examined for consistency and although the maximum variation between scales was less than 0.6% across the weight range of our subjects, correction equations were developed to standardize all weight measurements to a single scale.

Race participants were alerted in advance of the race that they would be asked to complete a post-race web-based questionnaire about hydration strategies. An invitation to the questionnaire was sent electronically to all race starters within a few hours of the end of the event. Those who had not completed the survey were sent reminder e-mails 7 and 12 days later. The
survey was closed 15 days after the race. The survey included a question asking whether the runner had or had not used sodium supplements beyond what they consumed in food and fluids (with examples provided as ‘such as S! Caps, Endurolytes, or table salt’) during each of four segments of the race defined by the sites where body weights were measured. The runners were also asked to indicate the main factor they had used to decide how much to drink during each race segment with the following options offered: thirst, a pre-determined drinking schedule according to distance or time, the maximum amount that could be tolerated, the amount of change in body weight, urine color, and other. The question indicated that they should select the ‘other’ option if there were multiple factors, and they were provided with an opportunity to explain their strategies.

Prior work examining hydration state based on body weight change from registration weight has used ≥0 weight change as overhydration, <0% to −3% change as euhydration, and <-3% change as dehydration (Noakes et al., 2005). Recognizing that a body weight loss of ~1% could reasonably be expected from fat use during a 161 km ultramarathon (Stuempfle et al., 2011), and that body weight is typically ~1% higher immediately before the race start compared with the prior day (Hoffman et al., 2013b), our recent work that used registration weight retained these percentages for defining hydration levels. Since the present work bases weight change on weight immediately before race start, we have shifted the percentages defining each hydration level down by 1% for this analysis. Therefore, we consider a weight change ≥−1% as overhydration, <-1% to −4% change as euhydration, and <-4% change as dehydration.

The relationship of percentage weight change with finish time was determined with Pearson correlation. Analysis of body weight across sites among the top-10 finishers was done with repeated measures analysis of variance (ANOVA) and the Scheffe post-test. Examination of weight across sites and between groups based on finish status or hydration strategies was accomplished with two-way repeated measures ANOVA and the Scheffe post-test. Between-group comparisons were made with unpaired t-tests for continuous data and Fisher’s exact tests for categorical data, except for the analyses of drinking strategies and use of sodium supplementation, which were analyzed with Chi-square tests. Statistical significance was set at $p < 0.05$.

**RESULTS**

The race had 383 starters, and 277 (72.3 %) finished under the 30-hour cutoff time. Overall, 272 (71.0%) of the starters completed the post-race questionnaire. Questionnaire participation was higher ($p = 0.0002$) among finishers ($n = 212, 76.5%$) than non-finishers ($n = 60, 56.6%$).
Weight change at the finish varied from –6.8% to 3.1% among the finishers, and there was no significant relationship between weight change and finish time (Figure 1).

The pattern of weight change during the race among finishers and non-finishers is shown in Figure 2. No significant group or interaction effects were present. However, both groups showed a mean weight decrease ($p < 0.005$) of approximately 2.5% from start weight by 48 km that was maintained through the remainder of the race.

Among the 277 finishers, 20.6% had weight loss >4% (dehydration), 50.2% had weight loss from >1% to 4% (euhydration), and 29.2% had weight gain or loss ≤1% (overhydration) at the finish. Among the 106 non-finishers, body weight measurements were obtained on 97 runners at a minimum of
one site prior to their dropping out. The weight change of this group, consid-
ering the last site where weight was measured, varied from −8.9% to 6.0%.
There were 22.7% with weight loss >4%, 52.6% with weight loss from >1% to
4%, and 24.7% with weight gain or loss ≤1%. There were no statistical
differences in weight change between finishers at the finish and non-finishers
at last weight measurement (p = 0.10) or in the proportions within each weight
change group (p > 0.4 for each comparison).

The pattern of weight change among the top-10 finishers is shown in
Figure 3. Individual data revealed various weight change patterns, but half of
the top-10 finishers had lost more than 2% of their body weight by 90 km, and
40% had lost over 3% by 126 km and 5–6% by the finish.

Table 1 shows the percentage of runners indicating use of different
drinking strategies and sodium supplementation across the four race seg-
ments. Drinking to thirst was the most common practice across all race
segments, but drinking the maximum tolerated and drinking to a predeter-
mined schedule were also common with the former being most common after
the initial race segment and the latter being more common in the initial race
segment. Use of sodium supplementation was very common and tended to be
most typical during the middle half of the race.

Figure 4 (top) shows the weight change for those using sodium supple-
ments across each segment compared with those not using sodium supple-
mentation across any segment. There were no significant group or interaction
effects present. Those not using sodium supplementation had a mean weight
loss of approximately 3%. Similar findings were present for the comparison of
weight change of those using sodium supplements and drinking the maximum
tolerated or to a pre-determined schedule across all segments completed with
those not using sodium supplementation and drinking to thirst across all
segments completed (Figure 4, bottom).

**FIGURE 3** Individual (thin lines) and mean (thick line) percentage weight change relative to
start weight for top-10 finishers. Statistical findings for weight change across sites: *p<0.05
compared with start weight. All statistical differences were with start weight. Reg = registration.
Comparison of select characteristics (age, sex, number of prior 161 km finishes, and years of ultramarathon running experience) and race performance (finish rate, finish time among finishers, and distance completed among non-finishers) between those who used supplemental sodium in each segment completed \((n = 199)\) and those not using supplemental sodium during any segment \((n = 12)\) showed no statistical group differences for any variable examined. Furthermore, no group differences were found for the same variables in comparing those using sodium supplements and drinking the maximum tolerated or to a pre-determined schedule across all segments completed \((n = 48)\) with those not using sodium supplementation and drinking to thirst across all segments completed \((n = 7)\).

**DISCUSSION**

The key findings of this study are that (1) the extent of weight change during a 161 km ultramarathon varied considerably among participants but did not differ between finishers and non-finishers; (2) in general, runners had lost over 2% body weight by 48 km and thereafter maintained a similar weight; (3) some top performers had lost more than 2% body weight relatively early in the race and continued to lose additional weight through the remainder of the race; and (4) drinking strategies and sodium supplementation had no statistical effect on weight change during the race. Based upon these findings, it appears that weight change is not a distinguishing factor between finishers and non-finishers, weight loss greater than 2% does not necessarily have serious adverse consequences on performance, and use of sodium supplements is not required for adequate maintenance of hydration during ultra-endurance events with high thermal stress.

**TABLE 1** Percentage of runners indicating use of different hydration strategies during the four segments of the race. The ‘Overall’ column represents the percentage of runners indicating use of the hydration strategy during any segment of the race. Percentages of drinking strategies for each race segment do not summate to 100 because some runners reported multiple drinking strategies.

<table>
<thead>
<tr>
<th>Hydration Strategy</th>
<th>0–48 km</th>
<th>48–90 km</th>
<th>90–126 km</th>
<th>126–161 km</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thirst</td>
<td>52.6</td>
<td>44.5a</td>
<td>51.5</td>
<td>57.6a</td>
<td>67.01,2</td>
</tr>
<tr>
<td>Maximum tolerated</td>
<td>13.3a</td>
<td>23.0a</td>
<td>22.0</td>
<td>18.9</td>
<td>34.41,3</td>
</tr>
<tr>
<td>Pre-determined schedule</td>
<td>27.4a,b,c</td>
<td>15.8a</td>
<td>14.5h</td>
<td>12.4a</td>
<td>29.6a</td>
</tr>
<tr>
<td>Change in body weight</td>
<td>3.7a,b,c</td>
<td>12.5a</td>
<td>10.0h</td>
<td>11.1c</td>
<td>18.1a</td>
</tr>
<tr>
<td>Urine color</td>
<td>6.3</td>
<td>7.2</td>
<td>6.2</td>
<td>4.1</td>
<td>10.0a</td>
</tr>
<tr>
<td>Other</td>
<td>5.2</td>
<td>3.0</td>
<td>3.3</td>
<td>1.4</td>
<td>7.0a,b,c</td>
</tr>
<tr>
<td>Sodium Supplementation</td>
<td>82.7a</td>
<td>95.5a,b</td>
<td>90.6</td>
<td>84.1b</td>
<td>95.6</td>
</tr>
</tbody>
</table>

*p*<0.05 between race segments with same letter considering the given hydration strategy

*p*<0.01 between overall drinking strategies with same number
Weight change varied from –6.8% to 3.1% among finishers and from –8.9% to 6.0% among non-finishers in this study. These percentages fall within the range previously seen for finishers of ultra-endurance competitions (Hoffman et al., 2013a; Hsu et al., 2009; Kao et al., 2008; Noakes et al., 2005; Sharwood et al., 2002, 2004; Speedy et al., 1997a; Speedy, Faris, Hamlin, Gallagher, & Campbell, 1997b; Wharam et al., 2006; Zouhal et al., 2011). However, a surprising finding, given the high ambient temperature conditions, was that only 20.6% of finishers lost over 4% of their body weight.
We have previously examined the relationship between the percentage of dehydrated finishers and ambient temperature in the same ultramarathon as the present study (Hoffman et al., 2013a). That work suggests that around 40% of finishers would be expected to have lost over 4% body weight under the temperature conditions of the present study.

It is logical to wonder how such a large percentage of runners in the present event avoided becoming dehydrated. Given that the largest proportion of runners used thirst as the main determinant of their fluid intake, it appears that drinking beyond the dictates of thirst is not required to maintain hydration. Furthermore, the use of sodium supplements had no significant effect on weight change, and those runners who did not use sodium supplements, including those who also drank to thirst, had a mean weight loss of approximately 3%. In other words, the runners not using sodium supplements were able to maintain euhydration. Therefore, we must conclude that drinking to thirst can be adequate and that no supplemental sodium is required to avoid dehydration, even during prolonged exercise with high thermal stress.

Weight assessment at intermediate locations during the event provided the opportunity to determine if weight change might be a determinant of whether a runner is able to finish the event or not. The present analysis revealed there to be no effect, whether comparing weight change at various intermediate locations between finishers and non-finishers, weight change at the last weigh-in before dropping out with finish weight among finishers, or the proportion of runners within different weight change categories between finishers and non-finishers. Therefore, the extent of weight change during an ultra-endurance event does not appear to be a factor that distinguishes between finishers and non-finishers.

The intermediate weight measurements also allowed for determination of whether top runners with greater than 2% weight loss might be maintaining weight for the majority of the race and only exceeding this amount of weight loss in the final stage of the race. On inspection of individual data (Figure 3), this does not appear to be the case, as it is evident that half of the top-10 finishers had lost more than 2% of their body weight by 90 km and 40% had lost more than 3% by 126 km. Therefore, it is evident that it is not unusual for top-10 performers to have beyond 2% weight loss for much of an event, suggesting that performance is not significantly impaired with weight loss of this level.

Regardless of the controversies about optimal hydration strategies, it is important to recognize the actual behaviors of athletes. This work demonstrates that approximately half of the runners in the present event used thirst as the main determinant of fluid intake when considering each race segment individually, whereas 67% used thirst as a determinant of fluid intake during at least one segment of the race. Sodium supplementation was reported by over 80% of the runners at every race segment, and reached over 95% in the segment that would have included the hottest ambient temperatures for
most runners. Our examination of hydration strategies two years earlier at the same event (Winger et al., 2013) found use of sodium supplementation (89.9%) to be comparable to the present study. But interestingly, the most common drinking strategy in that study (reported by 44%) was to drink to a predetermined schedule. At that time, only 17% reported their strategy was to drink to thirst. Therefore, it appears that there has been a positive shift in drinking strategies in the past two years, possibly related to educational efforts at this race and elsewhere. Still, when considering that over a third of the runners indicated that their main determinants of fluid intake were a predetermined schedule or the maximum amount tolerated, it appears that continued educational efforts are needed.

The study is limited by the observational design and that only a small proportion of runners chose to not use sodium supplementation. Owing to the strong beliefs among participants in the present event about optimal hydration strategies and sodium supplementation, it is not currently feasible to acquire an adequate sample size of runners who would agree to a blinded randomized controlled trial of sodium supplementation. Reliance on subject recall and response to a questionnaire is another potential source of error in this research. We sought to reduce this error by alerting race participants in advance that they would be queried on hydration strategies and by closing the post-race survey 15 days after the race to limit memory distortion. Given that most runners are unlikely to adopt a new hydration strategy for an event of this nature, we believe that there should be limited concern about recall error. However, there is a small potential for bias from a higher completion rate of the questionnaire among finishers compared with non-finishers, affecting the results of the comparison of group characteristics between those using sodium supplementation and those not using sodium supplementation. Nevertheless, an overall 71.0% participation rate is quite high.

Ultra-endurance athletes are commonly concerned about maintaining fluid and electrolyte balance, and the potential adverse effects that might result from dehydration. As a result, drinking beyond the dictates of thirst and use of sodium supplementation are widespread practices. This work supports prior evidence that performance may not be seriously impaired by weight loss greater than 2%. This work also demonstrates that ultra-endurance athletes can maintain adequate hydration by drinking to thirst and without using sodium supplementation beyond that taken in food and fluids, even when exercising in high ambient temperatures.

REFERENCES


