Hydration Recommendations for Sport 2008

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MONTAIN, S.J. Hydration recommendations for sport 2008. Curr. Sports Med. Rep., Vol. 7, No. 4, pp. 187-192, 2008. Fluid replacement remains an important strategy for preserving exercise performance as dehydration in excess of 2% of body weight consistently impairs aerobic exercise performance. Too much of a good thing, however, can have negative health consequences as persistent drinking in excess of sweating rate can induce symptomatic exercise associated hyponatremia. This short review highlights new position stands and/or policy statements regarding fluid replacement for sport, evidence that laboratory findings translate to team sport performance, and current hydration practices of athletes. It is culminated with practical strategies for drinking appropriately during physical activity.

INTRODUCTION

It is broadly accepted that fluid replacement is an important strategy for sustaining exercise performance. The basis for encouraging drinking is the consistent observation that dehydration in excess of ~2%-3% body mass (~1.5-2 liters of water for ~70 kg individual) impairs aerobic exercise performance. To facilitate replacement, fluids are made readily available to athletes during most sporting events.

Too much of a good thing, however, can produce adverse consequences. Persistent drinking in excess of sweating rate is associated with the development of exercise-associated hyponatremia (EAH) a potentially lethal condition (1–3). While EAH cases have primarily been limited to participants in marathon running races and ultramarathon endurance races (4), the condition can afflict any athlete with easy access to water or other electrolyte-poor drinks when they have relatively low sweating rates and a desire to drink copious amounts of fluid (5). It was the apparent increase in EAH incidence, particularly in events such as the 42 km marathon where EAH is an unexpected medical event that prompted critics (6,7) to charge professional organizations such as the American College of Sports Medicine (ACSM) with overzealous promotion of fluid replacement. In response, several professional organizations revised their fluid replacement advice.

Despite years of active investigation into the physiological consequences of water deficits, much of what we know regarding the consequences of dehydration is from laboratory experiments or field experiments investigating performance outcomes using relatively simple and quantifiable tests. However it is not known if the outcomes from the existing scientific literature are transferable to the complex nature of team sports. Moreover, most of the experiments have been limited to temperate and relatively warm environments. It is also not known if the same level of water deficit will compromise performance in cooler temperatures or if greater water deficit can be accrued before performance suffers. The interaction between the level of dehydration and environmental temperatures is just beginning to be characterized.

The purpose of this article is to highlight some of the new publications dealing with hydration and their contributions to our current understanding regarding fluid imbalance and fluid replacement recommendations for sport. The impact of exercise-induced fluid imbalances on performance/health have been the topic of a number of recent review papers (8–11), and the reader is referred to those reviews for greater detail regarding the physiological consequences, risk factors, and medical management of water imbalance.

NEW FLUID REPLACEMENT POLICY AND POSITION STANDS

Over the past few years, several new and/or updated fluid replacement policy or position stands have been published by professional organizations involved in sport or sport-relevant research. The International Olympic Committee (IOC) in 2003 held a consensus conference on the topic of nutrition for sports that considered fluid replacement. The
products of this meeting include a published consensus statement on Sports Nutrition (12), a review paper with recommendations for fluid and electrolyte replacement (13), and a practical guide written for athletes (14). The International Amateur Athletic Federation (IAAF) published a policy statement on fluid replacement (15) as well as practical guidance geared to the track and field athlete (16). In 2007, ACSM released an updated Exercise and Fluid Replacement Position Stand (9). A common theme of each document is that some dehydration is tolerable; the goal of fluid replacement should be to prevent dehydration (water loss) in excess of 2% body mass from accruing during activity. Moreover, each document includes language that drinking in excess of sweating rate should be avoided.

The 2007 ACSM Position Stand (9) includes a summary of current knowledge regarding exercise and fluid replacement as well as the impact of fluid-electrolyte imbalances on exercise performance and health. A new feature is the inclusion of Strength of Recommendation Taxonomy (SORT) to weigh the strength of evidence for each conclusion and recommendation. The document considers the various factors that contribute to and/or modify fluid and electrolyte requirements, describes practical techniques for assessing hydration state, and includes drinking strategies for before, during, and after exercise. The new Position Stand states that “the goal of drinking during exercise is to prevent excessive (>2% body weight loss from water deficit) dehydration and excessive changes in electrolyte balance to avert compromised performance.” Because of considerable variation between subject differences in sweating rate and sweat composition, the Position Stand recommends the athletes take personal responsibility for sustaining their hydration and develop customized fluid replacement programs.

THE IMPACT OF DEHYDRATION ON EXERCISE PERFORMANCE DEBATED

As part of the Contrasting Perspectives series in Medicine & Science in Sports & Exercise, Michael N. Sawka, Ph.D., FACSM, U.S. Army Research Institute of Environmental Medicine and Timothy D. Noakes, M.D., FACSM, University of Cape Town, recently (17) provided opposing perspectives to the question “Does dehydration impair exercise performance?” Dr. Sawka presented the prevailing view that performance can be expected to degrade when water deficits exceed ~2% body mass, whereas Dr. Noakes presented the challenging view, and conceded that dehydration degrades aerobic exercise performance. However, Dr. Noakes questioned the practical relevance of the “classically cited studies” to the real world of competitive sport and recreational exercise. This spirited debate provides an excellent summary of the evidence and illustrates why organizations such as ACSM, IAAF, and others have policy statements endorsing fluid replacement to sustain exercise performance. It also provides the opportunity for the reader to consider the merits of Dr. Noakes’ provocative alternative hypothesis that it is not the consequences of dehydration (e.g., increased osmolality and hypovolemia) that lead to compromised performance, but instead it is the development of thirst. Accordingly, he recommends that athletes drink according to the dictates of their thirst.

NEW INSIGHTS INTO THE NEUROBIOLOGY OF THIRST AND SALT APPETITE

Our ability to sense thirst and develop a salt appetite is made possible through an extensive neural network and the integration of information from multiple input pathways. Allen Kim Johnson, Ph.D., recently provided an extensive review that delineated the limits of our current understanding of thirst and salt appetite (18). This active area of research has included new insights into the contribution of mechanoreceptors in both stomach and proximal small intestine to modulate thirst (19), as well as the neuroanatomic pathways that link osmotic signals arising from the lamina terminalis cells to those brain regions responsible for changes in arousal and affect (20).

LABORATORY RESULTS TRANSLATE TO TEAM SPORTS

Laboratory studies investigating the consequences of dehydration on performance have consistently found that dehydration has little or no effect on muscle strength or ballistic power (8,21) but impairs the ability to perform aerobic exercise (8,17). Until recently, there was a paucity of studies investigating the threshold and functional impact of dehydration on team sport performance and/or individual sports demanding high levels of skill/precision such as tennis, soccer, and boxing. Over the past several years, more information regarding the consequences of dehydration on specific aspects of team sport performance has begun to emerge.

To test the effect of water deficit on soccer performance, McGregor et al. (22) examined the impact of drinking versus not drinking on ability to complete a 90 min variable intensity shuttle run with timed-embedded 20 meter all-out sprints, followed by a soccer dribbling test. The semi-professional soccer players who participated dehydrated by ~2.5% of initial body mass when fluids were restricted. Fluid restriction was accompanied by greater perception of effort late in the shuttle run protocol as well as degraded ability to sprint late in the shuttle run. Time to complete the soccer dribbling task was reduced 5% when no fluid was consumed, but maintained when fluids were consumed. A subsequent study by Edwards et al. (23) reported that soccer players accruing modest dehydration during exercise and match play (fluid deficit ~2% of initial body mass) perceived exercise and match play as more difficult compared to when fluids were consumed during breaks and finished with a higher internal body temperature. Consistent with McGregor et al., performance time was worse on the variable intensity running test designed to mimic the running pattern of a soccer match when fluids were restricted. A novel aspect of the Edwards et al. study was the inclusion of repeated mouth rinsing to attenuate subjective perception of thirst. While
mouth rinsing was somewhat effective at suppressing thirst, it was ineffective for preserving performance during match play. The importance of this observation is that it suggests that the slowing of running pace was attributable to the physiological challenge(s) imposed by excessive water deficit rather than development of thirst. Together, the two studies suggest that soccer players who accrue water deficits >2% body mass will have impaired ability to challenge for loose balls or dribble ball with the same velocity as when euhydrated. The effects on shot accuracy, passing, and most importantly on soccer team performance have not been examined.

Like soccer, basketball playing ability appears sensitive to water deficits in excess of ~2%–3% body mass. To examine impact of water deficit on basketball skill performance Dougherty et al. (24), and Baker et al. (25), had volunteers initially exercise in a hot room with and without fluid replacement followed by a simulated basketball game that contained embedded basketball skill tests. Dougherty et al. (24), reported that 12-to 15 yr-old players with water deficit of ~2% body mass made fewer basketball shots and were slower at sprinting and lateral movement tests. Baker et al., (25) manipulated drinking during the exercise-heat stress preceding a simulated basketball game so that the highly-skilled basketball players who participated performed a prescribed set of basketball drills embedded in the simulated basketball game with 1%, 2%, 3%, and 4% body mass loss attributable to dehydration. Consistent with Dougherty et al., time to complete a series of running drills was slower when dehydrated greater than or equal to 2% body mass and the magnitude of slowing increased with water deficit. While stationary shooting ability was remarkably consistent up to 4% body mass loss, the players attempted fewer shots and were less able to make shots linked with movement (e.g., lay-up) when dehydration had accrued to 3% and shooting was further impaired when performed when 4% dehydrated. Together, these studies support that performance degrades after body water deficits equal to ~2%–3% body mass. Given that sweating rates during basketball play can be expected to be between 1–2 L/h (8) and produce dehydration >2%–3% if fluids are not consumed, periodic drinking during games should be encouraged so as to minimize the negative consequences of dehydration on basketball ability. The mechanisms by which dehydration compromises basketball shooting accuracy remain poorly understood.

Devlin et al. (26) reported that cricket bowlers are less accurate when dehydration exceeds ~3% body mass loss. Thus, the loss of accuracy is not unique to basketball shooting. It has been shown that body sway is more pronounced after exercise and this effect is magnified when dehydration is present (27,28). Explanations for this deterioration in balance control include changes in vestibular function and/or vestibular afferent sensitivity (28,29). As deterioration in posture control would be anticipated to make it more difficult to reproduce complex motor movements, it may explain at least partially the decrease in shooting and throwing (fast bowling) accuracy accompanying dehydration.

The relationship between dehydration and performance may be affected by weather. Cheuvront et al. (30), recently reported that performance decrements observed in temperate laboratory conditions when 3% dehydrated were not apparent when the experiment was performed in cooler temperatures; suggesting that greater water deficits may be tolerable during exercise in cool weather. The effect, however, appears modest as water deficits equal to 4% normal body mass have been reported to compromise endurance performance despite cool temperatures (31). Therefore, cool weather does not negate the need to consider fluid replacement as a strategy for optimizing race performance, but may modestly increase the water deficit needed to impair exercise performance.

**ACCEPTABILITY OF CURRENT FLUID REPLACEMENT PRACTICES**

The current drinking behavior of athletes during both training and competition has received recent attention and is summarized in the Table. Overall, it would appear that most athletes are choosing appropriate drinking practices, as their behaviors driven by thirst or by cognitive choice, are preventing excessive dehydration. A recent survey (32) of college athletes revealed that: 90% of athletes were aware that dehydration can compromise exercise performance; 80% were aware that drinking before competition is a good practice so as to start exercise well-hydrated; and 70% of those same athletes practiced pre-exercise drinking. Thus, cognitive choice could be a contributor to success of their hydration practices. Somewhat troubling, however, is that

<table>
<thead>
<tr>
<th>Source</th>
<th>Sport</th>
<th>Type of Training</th>
<th>Ambient Temp., °C</th>
<th>Sweat Loss, L</th>
<th>Fluid Intake, L</th>
<th>% Body Mass Loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>(45)</td>
<td>Soccer</td>
<td>Training</td>
<td>24-29</td>
<td>2.0 (1.4–2.4)</td>
<td>1.0 (0.3–1.7)</td>
<td>1.4 (0.5–2.6)</td>
</tr>
<tr>
<td>(46)</td>
<td>Soccer</td>
<td>Training</td>
<td>32</td>
<td>2.2 (1.7–3.1)</td>
<td>1.0 (0.2–1.7)</td>
<td>1.6</td>
</tr>
<tr>
<td>(47)</td>
<td>Soccer</td>
<td>Match play</td>
<td>6-8</td>
<td></td>
<td>1.0 (0.1–2.2)</td>
<td>0.9 (0–1.8)</td>
</tr>
<tr>
<td>(48)</td>
<td>Tennis</td>
<td>Match play</td>
<td>30-31</td>
<td>1.5</td>
<td>1.1</td>
<td>0.9</td>
</tr>
<tr>
<td>(49)</td>
<td>Football</td>
<td>Training</td>
<td>28-31</td>
<td>4.2</td>
<td>2.6</td>
<td>1.7</td>
</tr>
<tr>
<td>(50)</td>
<td>Football</td>
<td>Training</td>
<td>25 WBGT</td>
<td>3.4</td>
<td>2.2</td>
<td>1.0</td>
</tr>
</tbody>
</table>

Data are mean (range). WBGT = wet bulb globe temperature.
PROBLEMS ASSOCIATED WITH OVERDRINKING - EXERCISE ASSOCIATED HYponATREMIA

Symptomatic EAH most commonly develops in individuals participating in marathon and ultramarathon endurance activities. Slower, smaller participants appear to be at most risk (33,34). EAH arises primarily from persistent overdrinking of fluids relative to sweating rate and the inability to excrete the relative fluid excess either during or in the initial recovery period (4,5,10,35). However, there is both theoretical (2) and observational (36,37) evidence that during ultramarathon activities, fluid replacement with water or other electrolyte-poor beverages can lead to dilution of plasma sodium below 130 mEq/L without overdrinking relative to sweating rate. As such, preventative strategies must consider both drinking rate and electrolyte replacement.

Several notions exist regarding the etiology of EAH that cause confusion but are not supported by scientific evidence. Two such notions are that EAH is due to third spacing (2) and/or movement of osmotically-active sodium into non-osmotic form/pool(s) (39). First, neither of these explanations are needed to explain the development of EAH, as the magnitude of sodium dilution is predictable based only on mass balance of water, sodium, and potassium (2,38). Second, experimental induction of hyponatremia leads to release of sodium from non-osmotic pools (e.g., bone) not vice versa (39). Therefore, it is very unlikely that either third spacing or movement of sodium into non-osmotic pools contribute to the etiology of EAH.

Media attention to the negative consequences of excessive fluid intake has helped educate endurance sport participants that there is no advantage to drinking in excess of sweating rate and persistent overdrinking can in fact be harmful to not only performance but to health. Unfortunately, the death of a runner participating in the 2007 London Marathon (3), is evidence that continuing education is necessary to eradicate this condition.

PUTTING HYDRATION SCIENCE INTO PRACTICE

Prior to activities that produce vigorous and sustained sweating, it is a good practice to drink 1 to 3 cups of water or other fluid to increase the likelihood of starting the activity well hydrated. During exercise, enough fluid should be consumed to prevent excessive water loss (>2% of body mass), but not so much that body mass increases. The easiest way to track acute hydration changes is to measure nude body mass before and after exercise. If body mass falls more than 2%, the individual is drinking too little; if body mass increases, the individual is drinking too much. If the combination of environment, exercise intensity, and duration result in fluid losses <2% of body mass without drinking, then fluid intake can be ignored during exercise, but the athlete should rehydrate properly before their next exercise bout. While sweating rate can be predicted reasonably accurately based on body mass changes, it should be recognized that body mass is lost during exercise independently of sweat losses, due to the exchange of oxygen and carbon dioxide, and respiratory water loss (40). When estimates of sweat rate are made during exercise, it is wise to use caution in using only fluid intake as the sole predictor of body mass change. The most accurate way to track acute hydration changes is to measure nude body mass before and after exercise.
durations of ~60 min, errors in prediction are fairly small. However, since metabolic gas exchanges and respiratory water loss account for 5% to 15% of mass loss during physical activity, sweat losses will be underestimated during multiple hour events if these contributors to mass loss are ignored.

During exercise lasting over 4 hours, the consumption of electrolytes can reduce the risk of developing hyponatremia (2,41). As illustrated in the Figure, EAH can be expected not only when an individual persistently drinks in excess of sweating rate (absolute overdrinking) but also when fluid intake of water or electrolyte-poor drinks exceeds electrolyte losses (relative overdrinking). The actual need for electrolyte replacement will, however, depend on the myriad of factors that determine sweat electrolyte losses (9,42). Both experimental studies (43) and theoretical models (2) have demonstrated that electrolyte ingestion (in concentrations comparable to commercial sports beverages, ~20 mEq/L) can attenuate the development of EAH consequent to multiple hours of sustained sweating. If large sweat and electrolyte losses are anticipated during an athletic event, the electrolyte deficits can be minimized by ingesting salt-containing food and beverages.

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References

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