Rice-Based Electrolyte Drinks More Effective Than Water in Replacing Sweat Losses During Hot Weather Training and Operations

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ABSTRACT

Heat-related injury presents significant threats to the health and operational effectiveness of Soldiers and military operations. In 2012, active component, U.S. Armed Forces experienced 365 incident cases of heat stroke and 2,257 incident cases of "other heat injury." Most of these occurred among recruit and enlisted personnel and most were under the age of 30. In conditioned military personnel, a rice-based oral rehydration solution was superior to water alone at maintaining body weight and, by inference, enabled Soldiers to better maintain their the state of hydration during prolonged exercise in high ambient temperatures. In view of the health risks associated with dehydration and their effects on training and operations, this study suggests that the consumption of beverages containing electrolytes and a rice-based carbohydrate is superior to the consumption of water alone in preventing dehydration and heat related illness.

KEYWORDS: *heat-related illness, dehydration, oral rehydration, water*

Introduction

Heat-related injury presents significant threats to the health and operational effectiveness of Soldiers and military operations. In 2012, active component, U.S. Armed Forces experienced 365 incident cases of heat stroke and 2,257 incident cases of "other heat injury."[1] Most of these occurred among recruit and enlisted personnel and most were under the age of 30.

Volume depletion that occurs from sweating during warm or hot weather operations and training contributes to exertional heat illness (EHI), including heat cramps, heat exhaustion, and potentially fatal heat stroke. The risk of EHI is associated with strenuous exercise at wet bulb globe temperatures (WBGTs) as low as 65°F. Among Marine recruits in training, rates of EHI increased 26 and 39 times over baseline for immediate and prior day exposures when WBGT increased from 65°F to 75°F–80°F, highlighting a further association between EHI and heat exposure on prior days.[2] EHI has been attributed to causing 12% of exercise-related deaths among Soldiers between the ages of 17 and 34.[3]

Acute weight loss that occurs when operating or exercising in the heat is due primarily to the loss of water and electrolytes (including sodium [Na^+] and potassium [K^+]) in sweat.[4–6] This acute volume loss from sweating occurs at the expense of the circulating intravascular volume. In non–heat-acclimatized persons, sweat contains increased amounts of sodium relative to water and potassium. With acclimatization, sweating occurs sooner, the rate of sweating increases, the sodium concentration of sweat decreases, and the concentration of potassium increases.[7]

The ability to sustain high levels of physical activity while training or operating in warm weather operations requires preserving body weight by remaining hydrated through the ingestion of both water and electrolytes, primarily sodium (NaCl) and potassium (K^+). In the current study, we measured acute changes in total body weight before and immediately after periods of vigorous prolonged exercise in non–fluid-restricted military personnel while training under warm conditions. We evaluated the ability of an electrolyte-containing sweat replacement drink to maintain the subjects' level of hydration compared with the consumption of water alone.

Methods

Changes in body weight were measured in military personnel exercising in hot weather to determine whether water alone or a rice-based electrolyte drink could better maintain body weight. Acute changes in body weight correlate with water loss and the state hydration. The study was a prospective crossover design comparing weight loss during exercise under tropical heat conditions. Each participant acted as his or her own control to factor out individual variability. On day 1, Soldiers were permitted to consume only water while training. On day 2, water was substituted for a rice-based oral

electrolyte drink (CeraSport; Cera Products, Inc.). This study design was intended to eliminate the variation in sweat rates and body mass index among the participants. In three groups tested, 52 completed the 2 days of exercise. Statistical analysis was used to calculate the mean and 95% confidence limits comparing the weight loss on the day water was consumed with that on the day the participants consumed CeraSport.

Participants were all Soldiers ranging in age from 18 to 29 years; each had up to 9 years of military experience, and all were airborne qualified. Morning temperatures were 65°F on day 1 and 71°F on day 2. The exercise lasted 2.5 hours and consisted of trail running on hills with five stops for pushups, sit-ups, flutter kicks, pull-ups, and sprints. All participants were weighed at the start of the exercise and at the end, following a change into dry identical clothes.

Results

Of the 54 Soldiers, 52 completed the study (2 withdrew). Soldiers lost significantly less weight when consuming CeraSport compared with when they consumed water alone ($p < .001$) (Table 1).

Table 1 *Absolute and Percent Body Weight Loss During Hot Weather Exercise by Conditioned Military Personnel Who Drank Water on Day 1 and a Rice-Based Electrolyte Drink on Day 2*

	Day 1 (N = 52)	Day 2 (N = 52)
Range loss, lb	–1.0 to –8.0	–0.2 to –6.0
Range, % loss body weight	–0.1% to 3.1%	–0.1% to 3.1%
Mean loss, lb	–3.17 ± 1.40†	–2.53 ± 1.15†
Mean, % loss body weight	–3.71% ± 1.71*	–1.85% ± 1.23*

Notes: *p < .001.
†Standard error of the mean.

Discussion

Throughout history, military medical providers and commanders have recognized the ability of dehydration and heat-related illness to degrade a Soldier's and thereby a unit's operational capability and status during military campaigns.[8] The Bible, historical references to ancient battles, data from World War II, and experiences in Afghanistan and Iraq all highlight the morbidity and mortality associated with EHI. In addition to impairing operational effectiveness, heat illness results in considerable morbidity during recruit training, and heat stroke remains a common cause of preventable nontraumatic exertional death in the U.S. military.[9,10]

The consumption of water alone during prolonged physical exertion and high sweat rates is insufficient to replace water and electrolyte losses and place Soldiers at risk for hyponatremia. Hyponatremia is the low concentration of sodium in the blood (< 135 mEq/L) and is associated with serious and sometimes fatal medical consequences that include cerebral edema, seizures, and death. From 1999 through 2012, 1,333 incident cases of hyponatremia were reported among active component, U.S. military personnel. Fortunately, the implementation of training and a fluid replacement policy that included limitations on water consumption to 1.5 quarts of water per hour and 12 quarts per day have reduced the peak incidence in 2010 by 50%. In 2012, there were only 84 cases of hyponatremia reported, the lowest number in the previous 6 years.[11] When electrolyte losses from sweating are replaced by salt tablets (NaCl) alone, potassium depletion occurs. Over time, chronic potassium depletion may result in muscle weakness, paralysis, and even death.[12] Salt tablets are also difficult to digest and are known to cause local irritation in the esophagus and upper intestinal tract.[13]

The absorption of sodium and water by the small intestine is enhanced substantially by a robust, independent glucose-sodium carrier-mediated system. At present, the majority of commonly consumed electrolyte-containing sports drinks use glucose or other simple sugars as their carbohydrate. Simple sugars make these beverages hyperosmotic compared with blood plasma. When drinks exceed an osmolality of 300mmol (due primarily to the sugar in the beverage), the increased osmolality causes salts and water to translocate from the portal circulation into the bowel lumen, temporarily reducing the circulating blood volume. This can result in diarrhea, distention of the small bowel causing bloating and crampy abdominal pain, and *hypovolemia*.

This translocation of consumed fluids into the small bowel (i.e., dumping syndrome) is preventable by avoiding sports drinks that are hyperosmolar compared with plasma. The substitution of low-osmolar, readily digestible complex starches for simple sugars permits the rapid absorption of water and electrolytes from small bowel while reducing the incidence of gastrointestinal distress.

In this study, CeraSport was used as the electrolyte-containing beverage. This beverage contains partially hydrolyzed rice as the carbohydrate. Intestinal enzymes are able to rapidly digest this low-osmolar carbohydrate, liberating low concentrations of glucose, which then facilitates the absorption of sodium and water by a carrier-mediated transport mechanism.[14] This results in the net absorption of fluid into the circulation without causing a transient loss of intravascular volume into the upper intestinal tract. The proof of principle is well

documented in studies comparing the replacement of diarrheal losses by either glucose- or rice-based oral rehydration solutions.[14]

The limitations of our pilot study are that it is small and that we were unable to blind the two test beverages (water and CeraSport). However, the outcomes were statistically significant, suggesting a clinically important difference exists that favors the consumption of CeraSport over the consumption of plain water when exercising in warm environments.

Bias in this study could have occurred if the conditions of heat and humidity differed significantly on the 2 test days. The temperatures on the study days were comparable (slightly warmer on the CeraSport day), and each individual acted as his or her own control. We do not believe that this should confound the results. Future studies are warranted to compare CeraSport directly against electrolyte sports drinks containing glucose. Additional study design measures should include additional measures of hydration, body chemistry, and environmental factors. Increasing the number of study participants and including physiologic measurements of hydration such as serum and urine electrolytes, serum osmolality, blood urea nitrogen, creatinine, bioimpedence, and urine specific gravity as indicators of hydration along with heat stress measures such as WBGT and thermal work limit may provide additional information on determining the optimal fluid needed to maintain peak performance when exercising in warm environments.[15]

Conclusion

In conditioned military personnel, a rice-based oral rehydration solution (i.e., CeraSport) was superior to water alone at maintaining body weight and, by inference, enabled Soldiers to better maintain their state of hydration during prolonged exercise in high ambient temperatures. In view of the health risks associated with dehydration and their effects on training and operations, this study suggests that the consumption of beverages containing electrolytes and a rice-based carbohydrate is superior to the consumption of water alone in preventing dehydration and heat related illness. Future studies should include a comparison of rice-based oral rehydration solutions against those containing more osmotically active glucose.

Disclosures

The authors have nothing to disclose.

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