# Mitigating Exertional Heat Illness in Military Personnel

## *The Science Behind a Rice-Based Electrolyte and Rehydration Drink*

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## ABSTRACT

**Background:** Exertional heat illness continues to be prevalent among members of active duty personnel, especially those in specific military occupational specialties such as loadmasters, flight crew, flight maintainers, and Special Operations Forces. Therefore, the primary objective of this article was to elucidate the various oral rehydration solutions (ORSs) on the market that are used to mitigate exertional heat illness (EHI) in military personnel, and to focus on the science behind a rice-based electrolyte drink, CeraSport®, currently used by US military personnel in mitigating EHI during sustained training operations in high-heat environments. **Methods:** A search of the literature (through March 2016) was performed using PubMed and ProQuest, in addition to searching bibliographies and text books. We reviewed 63 articles and three texts. Articles were limited to those published in English and to studies that used only carbohydrates (e.g., no amino acids) and drinks reported to be used by the military in field training and deployment. **Conclusion:** Heat illness is prevalent among military personnel operating in high-heat environments and a variety of ORSs and sports drinks are available to help mitigate this. However, CeraSport, compared with other ORSs and sports drinks, may offer benefits such as faster gastric emptying rates and improved absorption from the gastrointestinal tract, which can provide rapidly available carbohydrate substrates for energy needs, and increased water retention for maintenance of blood plasma volume.


KEYWORDS: *Special Forces; physical training; heat illness; oral rehydration solutions; physical performance*

## Introduction

Exertional heat illness (EHI) continues to be prevalent among active duty personnel and poses a significant threat to their health and may impair mission and operational training effectiveness. According to the Defense Medical Surveillance System, which is used to record and track hospitalizations and ambulatory visits of actively serving military personnel in the Army, Air Force, Marine Corps, and Coast Guard worldwide, 720 incidents of heat injuries were diagnosed and documented among military personnel serving in Iraq and Afghanistan, and 6.9% of these diagnoses were for heat stroke. Additionally, 1,953 cases of "other heat-related injuries" were reported in 2015 for all Servicemembers.[1] In addition to hot, humid conditions, protective clothing such as personal protective equipment may induce heat injuries even when environmental conditions alone do not impose a significant threat and when wet-bulb globe temperatures are as low as 65°F.[2]

Although consistent water consumption plays a major role in preventing heat injury, it may not be sufficient by itself to prevent illness and may actually cause a condition known as hyponatremia, defined by a serum sodium concentration of less than 135mmol/L.[3] Sports drinks containing electrolytes such as sodium and chloride ions, as well as various sources of carbohydrates are frequently recommended to increase water absorption and retention, and prevent dangerous drops in serum sodium levels. For example, in a comparison study involving highly fit Soldiers performing high-volume operational training in hot weather, Gerold and colleagues[2] found that a rice-based carbohydrate drink (CeraSport®; Cera Products, http://ceraproductsinc.com/) was superior to the ingestion of water alone in maintaining body weight, inferring that the Soldiers could better maintain hydration status during high-volume training in hot weather conditions. Additionally, other approved drinks currently used during military training operations may not provide sustained energy, performance, and hydration because of their nutrient profiles.[4] Nonetheless, they recommended that future research should be conducted comparing CeraSport with other sports drinks containing more osmotically active glucose.[2]

Most oral rehydration supplements (ORSs) contain concentrations of various electrolytes such as sodium and chloride ions as well as carbohydrates (CHOs), which consist mostly of differing concentrations of the monosaccharides glucose and fructose or of the disaccharide sucrose, which consists of a fructose and a

glucose molecule. An alternative option to these choices is CeraSport, which contains sodium and potassium but provides an alternative CHO derived from rice. The processing of the rice starch is reported to result in a product that contains glucose, maltose (a disaccharide of two glucose molecules), as well as medium- and long-chain maltodextrins (MDs), which have lower osmolality. The MDs in CeraSport may reach the ileum in the distal small intestine, in contrast to other CHOs that may be absorbed in the proximal small intestine (duodenum and jejunum), and subsequently may provide sustained-release CHOs for energy. The greater availability of CHO molecules is important, considering a 2% loss of body weight impairs cardiovascular and temperature regulation, which may result in decrements in physical performance.[5] Additionally, hypohydration (lower than normal volume of water in the body) is known to alter cardiovascular function. Specifically, it causes the heart rate (HR) to increase in an attempt to maintain cardiac output (CO) as stroke volume (SV; the amount of blood pumped from the heart per contraction) decreases (thus, CO = HR × SV).[6] One of the primary determinants of blood pressure is CO; therefore, altered CO affects blood pressure regulation.

Maintaining hydration, energy, and performance is critical during war and training, because military personnel are routinely exposed to a variety of environmental conditions that can alter judgment and physical performance and even result in death. For instance, when a Servicemember suffers from a heat-related illness of any kind, an estimated four members of the platoon are needed to carry that member any distance. Therefore, use of an ORS could help ameliorate heat illness among military troops, thereby reducing exertional EHI and improving field performance.

CeraSport, a spinoff of CeraLyte 70, was specifically named in preference to generic glucose-based ORSs as a requirement for inclusion in all individual first aid kits and flight jackets in 2005 by Lieutenant General George Peach Taylor Jr, MD,[7] who was the Air Force Surgeon General at the time. Before CeraLyte 70 was included in individual first aid kits, the US Air Force completed internal studies comparing CeraLyte 70 with traditional fluids administered intravenously. Unfortunately, results from these internal studies were unavailable to us. CeraLyte 70 is reported by the manufacturers to contain 70g of long-chain rice CHO combined with a 50:20 sodium and potassium ratio, and has an osmolarity of <200mOsm/L compared with other oral rehydration solutions, which may have an osmolarity of ≥275mOsm/L. The low osmolar concentration in CeraSport coupled with the long-chain CHOs may result in increased absorption rates in the small intestine and is reported to reduce the incidence of gastrointestinal distress.[2]

*Physiological Importance of Various CHOs*

In foods, CHOs make up one of the three categories of macromolecules in the diet. Nutrient sources of CHOs are important components for energy production in the human body. One of the main sources of CHO in the diet is starch (differing types are defined by their three-dimensional structure), which consists of long chains of glucose molecules connected through α 1,4 linkages between the glucose molecules. The straight chains of one type of starch, amylose, allow the CHO to form a tightly coiled α helix whose structure may inhibit efficient digestion. A different form of starch, amylopectin, consists of these long-chain molecules but with the addition of branches of glucose chains at various points off the main structure that form through an α 1, –6 linkage. This branching prevents the amylopectin molecules from winding tightly into the helix coil, and thus allows a more open three-dimensional structure. This open structure enables greater access to the digestive enzymes, allowing amylopectin to be digested more quickly and efficiently than the α helix structure of amylose. This branch-chain feature is reported by the manufacturer to be a component of the CHO in CeraSport.

The efficacy of CHOs in drinks is further defined by rates of digestion and absorption in the gastrointestinal tract (GIT), which are determined by anatomic structure. The surface of the small intestine (where most CHO digestion and absorption occurs) facing the lumen is folded into projections called villi, which increase the surface area by about 10-fold. The surface is further increased by the columnar epithelial cells lining the villi; these form additional projections called microvilli, which make up the brush border. Discrete filaments of sulfonated proteins are part of the glycocalyx (i.e., the fuzzy layer over the top of the microvilli). These sulfonated proteins are structural and hydrophilic, aligned in parallel with each other, and make up part of the unstirred layer, so named because it does not move during peristalsis (i.e., the muscular contractions that move the contents along the GIT). Because there is no movement within this region, molecules move only by diffusion, and this rate of diffusion plays a distinct role in rates of digestion. The rate of diffusion is a function of the concentration of the substrate or CHO and the size of the molecule, with larger molecules moving more slowly than smaller ones.[8] However, the slower rate of diffusion of the larger MD molecules may be offset by the faster rate of absorption of glucose from MD as compared with individual glucose molecules because the enzyme complexes that hydrolyze CHO are reported to be in proximity to the CHO transporters.[8] This phenomenon has been demonstrated in several studies, which provide evidence that glucose from maltose or maltotriose is absorbed faster than from glucose itself.[9–13]

Several researchers have compared the use of various types of CHOs in sports drinks for support of athletic performance (e.g., comparisons of galactose [from lactose], fructose, maltose, and/or sucrose). Glucose monomers are absorbed via a sodium-dependent transporter (SGLT1), which can transport both glucose and galactose,[14] whereas fructose is transported via a sodium-independent transporter, GLUT5.[15] The differing transporters for glucose and fructose prevent competitive inhibition at the brush border, which means that the presence of one does not slow the transport of the other, permitting higher concentrations of absorption of the monomers. However, this apparent advantage of the presence of fructose in a sports drink may be offset by the necessary conversions of fructose to glucose before oxidation for energy support.[16]

Previous studies have provided evidence that the CHOs' structure and concentration play important roles in absorption rates from the GIT as well as oxidation for energy production within the body. For example, in vivo perfusion of human duodenal tissues perfused with glucose or maltose provides evidence that glucose monomers hydrolyzed from the maltose disaccharide are absorbed more quickly than when glucose is provided as the monomer itself.[10,12] Although increasing the CHO concentrations may compensate for the faster rate of absorption of glucose from maltose,[9] the concentrations of CHO containing various glucose molecules of varying chain lengths may allow greater absorption and use of glucose compared with drinks containing glucose from mono- and disaccharides alone. Although Anastasiou et al[17] reported no differences when MD was added to a sports drinks (provided to cyclists and tested after fasting) in comparison with glucose and maltose, the experimental design added MD in the same amount (4.9g) to all drinks, making it impossible to clearly delineate its effect. Additionally, although higher levels of CHO intake, such as a combination of glucose and sucrose, increased oxidation rates of exogenous CHO,[18] these were provided in a higher concentration than is preferred for palatability (i.e., 270g of CHO over 2.5 hours). Using MDs, which are less sweet, as a source of glucose in a sports drink may increase palatability, which, in turn, may result in increased consumption, especially in hot environments, whereas, an overly sweet taste (e.g., in drinks containing combinations of fructose, sucrose, and glucose) may decrease intake.

Various rates of exogenous CHO oxidation tested in athletes have been reported previously. Although MD combined with fructose has been reported to increase CHO oxidation rates,[19] other studies have not reported any significant increase in athletic performance when fructose is combined with MD.[20] One confounding factor among comparisons of differing CHO substrates is the differing rates of ingestion. Higher rates of consumption of drinks with higher concentrations of CHO appear to increase CHO oxidation rates, regardless of CHO source.[16] However, in the field, higher concentrations of CHO in the drink may adversely affect consumption.

### *Key Mechanisms of Action*

Gastric emptying rates are frequently identified as a factor in athletic performance. Slower emptying rates have been associated with increased gastric discomfort, decreasing athletic performance. Gastric emptying rates as well as total oxidation of exogenous CHO are faster for glucose polymers than for glucose alone. When solutions of glucose, sucrose, and glucose polymers (GPs; e.g., MD) at varying concentrations (7.5%, 10%, or 15% weight per volume) and molecular weight ($GP_{11}$ and $GP_{22}$) were compared, results indicated that glucose had the slowest gastric emptying rate.[21] Overall, total exogenous CHO oxidation rates were greater for GPs than for glucose and may indicate a decided advantage to the use of GPs in a sports drink compared with those consisting primarily of glucose. The longer the chain length, the greater the oxidation rate, which may indicate that the digestion and absorption rates are greater for the GPs as compared with single molecules or disaccharides. Higher oxidation rates of GPs would also translate to greater energy available to the athlete.

Maintenance of body-water homeostasis is crucial to health of the host and is referred to specifically as normohydration, or euhydration. Osmolality is defined as the concentrations of solutes, or dissolved substances, in various bodily fluids and affects water transport and retention between the inside of the gut and the inside of the host.[4] The lower osmolality of CeraSport compared with other sports drinks may allow better absorption of water from the GIT into the blood stream, maintaining positive hydration status and decreasing the risk of EHI, thereby mitigating EHI during prolonged battlefield and training operations. Measurement of pre- and postexercise body weight (a reliable indicator of hydration status) of Soldiers who consumed either water or CeraSport during prolonged exercise in hot weather revealed significantly greater body weight maintenance when CeraSport was consumed, indicating a more positive hydration state,[2] thus decreasing the risk of EHI.

Additionally, it is imperative that consumption of CHOs during prolonged military missions is sufficient to sustain energy levels and maintain cognitive function of personnel. Cognitive function is influenced by hydration status and maintenance as well as glucose concentrations,

because the brain preferentially uses glucose as the primary source of energy, requiring approximately 50% of the glucose consumed.[6] The small intestine consists of three functionally defined sections: the duodenum (closest to the stomach), the jejunum (midsection), and the ileum (closest to the colon). Glucose is primarily absorbed in the duodenum and jejunum by SGLT1 in conjunction with two sodium ions.[22] However, recent data indicate that at least two different glucose transporters are present in the ileum.[23] In contrast to other sports drinks containing sugars (mostly absorbed from the duodenum), the longer CHO chains in CeraSport may decrease digestion in the duodenum/jejunum and allow more of the CHO to reach the ileum, which may result in a slower and more sustained release of glucose, supporting energy status as well as cognitive function.

## Conclusion and Recommendations

Heat illness is prevalent among military personnel operating in high-heat environments, and a variety of ORSs/sports drinks are available to help remediate this issue. However, after extensive review of the literature, CeraSport, compared with other ORSs/sports drinks, may offer benefits such as faster gastric emptying rates; improved absorption from the GIT, which can provide rapidly available CHO substrates for energy needs; and increased water retention for maintenance of blood plasma volume (better hydration status). Additionally, there may be other biochemical and physiological benefits for military personnel using CeraSport versus other sports drinks, especially during prolonged field training operations in hot and humid environments. Further testing is needed to clarify these biochemical and physiological differences for maintenance of operational effectiveness of military personnel.


## Funding

This work was supported by the US Air Force School of Aerospace Medicine and grant money through a Collaborative Research Agreement between CeraProducts and the US Air Force. The authors have no personal financial conflicts of interest.


## Disclaimer

The views expressed in this article are those of the authors and do not necessarily reflect the official policy or position of the Air Force, the Department of Defense, or the US Government.

## Disclosures

The authors have nothing to disclose.

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