# Hydration

## *Tactical and Practical Strategies*

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ABSTRACT

Full-spectrum Human Performance Optimization (HPO) is essential for Special Operations Forces (SOF). Adequate hydration is essential to all aspects of performance (physical and cognitive) and recovery. Water losses occur as a result of physical activity and can increase further depending on clothing and environmental conditions. Without intentional and appropriate strategic hydration planning, Operators are at increased risk for degradation in performance and exertional heat illness. The purpose of this article is to highlight current best practices for maintaining hydration before, during, and after activity, while considering various environmental conditions. Effective leadership and planning are necessary for preparing Operators for successful military operations.

Keywords: *hydration; special operations forces; SOF; human performance optimization; HPO; nutrition*

## Introduction

Water is an essential nutrient and is critically needed for Human Performance Optimization (HPO). Water helps maintain intravascular volume, regulates body temperature, eliminates waste, and allows for muscle contraction. Without sufficient water, blood pressure could not be maintained, and organs would not receive adequate blood, which would ultimately lead to organ failure and death. However, fluid needs vary based on age, type of activity, fitness level, acclimation status, clothing, and environmental conditions.[1] Average daily fluid intake for Operators should be 2 to 5 quarts (qt) (64–160 fluid onces (fl oz) but may be as high as 8 to 10-qt (256–320 fl oz) of water.[2] Note, one quart is equal to 32 fl oz or approximately 1L or 1,000mL.

## Dehydration

The human body operates best within a narrow temperature range. When exercising, the body produces excess heat, and if that heat is not dissipated efficiently, core body temperature will rise. Likewise, when sitting in a moderately hot environment, the body must work to rid itself of excess heat to maintain normal body temperature. First, heart rate increases to deliver more blood to the periphery and skin to release excess heat from the body to the environment, and sweating occurs. The body releases water onto the surface of the skin as sweat, which then directs more blood towards the skin surface. Thus, both heat and water are lost. Although this does help resolve the issue of excess heat production, it also increases the likelihood of dehydration. Dehydration is defined as the process of going from a state of euhydration ("good" or normal hydration) to hypohydration (insufficient amount of water). If dehydration is not addressed through appropriate and strategic hydration/fluid replacement plans, it can lead to performance (physical and cognitive) detriments, heat illness, and even loss of life. Environmental factors, including ambient temperature, humidity, and atmospheric pressure, can accelerate the onset and degree of dehydration. For example, fluid losses may be greater at altitude, in the cold, and in the heat compared to normobaric, thermoneutral conditions, even with low levels of physical activity.[1,3,4]

Dehydration can predispose an Operator to heat illness and can cause significant cognitive and physical performance detriments to an individual's performance depending on the level of dehydration.[1,5] Mild dehydration is defined as water loss leading to a 1–2% loss of body weight, moderate dehydration is a 2–5% loss of body weight, and severe dehydration is a loss of body weight greater than 5%.[6,7] For reference, a 2–3% loss of water in a 175-pound Operator would translate into 3.5- to 5-pound loss in body weight.

## Fluid Ingestion and Timing

Fluids should be consumed before, during, and after physical training or missions, depending on the venue. Operators should strive to be well-hydrated prior to physical exertion, which can be achieved by consuming 14–22 fl oz of liquid 2–4 hours prior to the activity.[1,4] For more personalized recommendations, fluid ingestion can also be specified according to body weight: approximately 2–4mL per pound of fluid is generally adequate to hydrate an Operator prior to engaging in physical activities.[1,4] Further, fluids containing small amounts

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of sodium (460–1,150mg/qt) are most effective for ensuring adequate hydration status before exercise. Sodium can also be ingested from food.

During physical activity, Operators should aim to replace fluids at a rate that would prevent losing more than 2% of their body weight.[1,4] Practically, this translates into 16–32 fl oz per hour. Most will find that consuming fluids at regular intervals (i.e., 4–8 fl oz every 15 minutes) is better tolerated than drinking all fluids at one time. However, each Operator should monitor his or her own fluid losses because these general recommendations do not account for individual differences. Some will be very heavy sweaters, and others may be heavy salt sweaters. Sweat rates have been reported to vary from 0.16 to 5.73L per hour, depending on age, type of activity, physical fitness, acclimation status, clothing, and, of course, environmental conditions.[1,8] Further, for sustained physical activity lasting more than one hour, a combination of fluid, electrolytes, and carbohydrates (e.g., sports drinks) should be considered.[1,4] Fluid intakes should not exceed 48 fl oz per hour. Table 1 provides criteria to consider when selecting a sports drink.

**TABLE 1** *Criteria for Sports Drinks*[1]

| Ingredient | Amount per 8 fl oz |
|---|---|
| Sodium | 82–163mg |
| Potassium | 16–46mg |
| Carbohydrate | 12–24g |

After physical activity, fluid losses need to be replaced. Hydration status can be restored by consuming regular foods and beverages.[1,4] More specifically, if actual changes in body weight are known, a one-pound loss in body weight would require ingesting 16–24 fl oz of liquid to fully restore balance.[1,4] Ideally, the fluid should contain sodium at a concentration of approximately 250mg per 8 fl oz to stimulate thirst and fluid retention, and promote a more rapid and complete recovery.[1,4] Sodium recommendations can also be met through food (e.g., pretzels, crackers, soup, deli meat, jerky, etc.). Additional fluids should be incorporated throughout the day rather than consumed in a short interval. Table 2 provides a summary of fluid recommendations before, during, and active physical activity.

## Monitoring Hydration

Hydration status is most easily monitored by changes in body weight, and a baseline measurement can be established by obtaining a first morning body weight over several days. Ideally, nude weight should be recorded both before and after physical activity to estimate fluids lost through sweating. In the field, a refractometer can be used to measure urine specific gravity (USG), another indicator of hydration status.[9] A USG ≤1.020 is desirable and reflects adequate hydration.[9] Alternatively, urine color can subjectively assess hydration, in which pale yellow, almost clear urine suggests adequate hydration, and dark yellow or smelly urine often indicates dehydration (Figure 1).[9] However, urine color may be altered if certain B vitamins, namely riboflavin, are being taken in large amounts. Likewise, eating beets may cause the urine to appear brown or dark red.

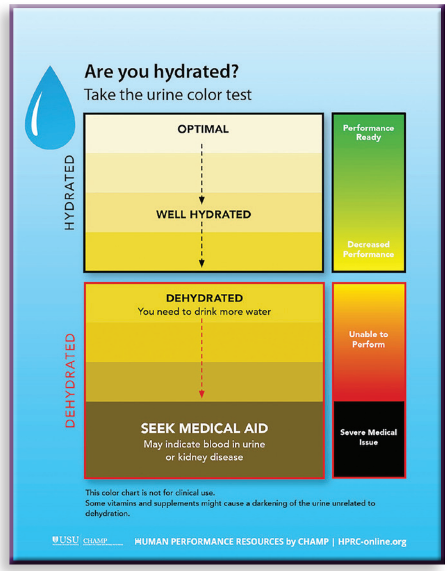


**FIGURE 1** *Urine color chart.*

*This chart can be used to rapidly assess hydration status. Urine capture should occur in a clear or white cup.*

Image created by Human Performance Resources by CHAMP (HPRC) at the Uniformed Services University, Bethesda, MD.

## Electrolyte Monitoring

Electrolyte (e.g., sodium, potassium, chloride) and mineral (e.g., calcium, zinc, iron) losses from sweating can be substantial, with sodium losses ranging from 50–7,000mg/hr, with higher values noted in heavy sweaters and those unaccustomed to working in the heat.[10–12] Potassium losses may range from 25–2,000mg/hr.[1] As such, commercial fluid replacement beverages typically provide sodium and potassium; some also provide magnesium and calcium as well, but the amounts typically are low. The recommended ranges for sodium and potassium to offset sweat losses and promote fluid absorption are 20–30mEq/L (460–700mg/L) and 2–10mEq/L (78–390mg/L), respectively.[1] Chloride is the only anion recommended as it optimizes fluid absorption. Importantly, loss of electrolytes cannot be estimated from changes in body weight.

## Special Populations

Certain populations of warfighters are at risk for dehydration due to tactical gear configurations, equipment and/or transportation used, and mission types.

### *Pilots/Aircrew/Parachutists*

One such population are aviators and aircrew who fly in tactical aircraft and/or helicopters. Dehydration is commonly reported in aircrew populations and can be attributed to high operations tempo and difficulty with urination in flight.[6] Aircrew have been known to intentionally dehydrate themselves,

**TABLE 2** *Fluid Recommendations Before, During, and After Physical Activity*

| Duration | Pre-Physical Activity (2–4 hours prior) | During Physical Activity | Post-Physical Activity |
|---|---|---|---|
| <60 minutes | 14–22-oz water (2–4mL/lb) | Drink water to thirst | 20–24 fl oz water per pound of body weight lost |
| ≥60 minutes | 14–22-oz water (2–4mL/lb) | 16–32 fl oz per hour, adjust carbohydrates and electrolytes based on environment and sweat rate; no more than 48 fl oz per hour | 20–24 fl oz water per pound of body weight lost. Additional fluids consumed throughout the day, combine with foods containing sodium; daily fluid intake should not exceed 384 fl oz (12 qt) per day |

known in some communities as "tactical dehydration," which is the deliberate practice of reducing fluid intake in the hours prior to flight to avoid having to urinate during flight. As some flight profiles can extend into multiple hours, mild to moderate dehydration can lead to decreases in attention, memory, and psychomotor skills.[6,13] Further, dehydration can predispose aircrew and Operators to hypoxia and, potentially, decompression sickness.[14]

Factors including high altitude, environmental heat stress, dynamic flight profile, and increases in insensible fluid loss when breathing on aircraft or closed oxygen systems (low humidity breathing gas) exacerbate fluid loss leading to acute dehydration and ultimately metabolic acidosis. Symptoms of metabolic acidosis include confusion, fatigue, and muscular fatigue. Depending on the severity, small changes in the amounts of acid or base can drastically change blood pH within a matter of seconds to minutes. The human body compensates with multiple, complex buffer systems that can take hours to days. Therefore, the situation may not be correctable during the mission/flight.

Dynamic flight operations have the propensity to generate high accelerative forces and loads, known as G-forces. There are three axes of acceleration, Gx, Gy, and Gz, and, for the purposes of this article, we are concerned with the Gz axis as it applies to the acceleration acting in the head to feet axis. Positive Gz (+Gz) forces are from the head to the feet (the most common direction of acceleration in aviation), negative Gz (-Gz) forces are from the feet to the head. Dehydration is known to reduce G-tolerance in individuals, making them more susceptible to G-related disturbances, such as visual disruptions (gray-out and blackout), near loss of consciousness, and G-induced loss of consciousness (G-LOC). G-LOC can occur in aircrew during sustained, high-Gz turns in which external forces of gravity counteract and/or reduce the flow of blood to the brain, creating cerebral hypoxia and, ultimately, unconsciousness. The reduction in G-tolerance is likely related to the reduction in circulating plasma volume and increases in cardiovascular strain.[15]

Although more frequently associated with tactical jet aircraft, G-related symptoms have been experienced in military helicopters.[16] In one study, sweat loss was measured in various military aircraft under similar conditions, and although tactical jet aircraft had the highest rate of fluid loss per hour, helicopter pilots had higher amounts of fluid loss per flight due to longer duration (time) flights.[17] Additionally, G-induced disturbances could potentially occur in parachutists under canopy (especially if dehydrated) when using spiral turns to descend rapidly (a long, hard pull on a steering toggle can cause a sustained, tight turn greater than 360°) when using high-performance parachutes. This type of turn can create a large bank angle and swing the parachutist's feet out of the turn, which can potentially reduce blood flow to the brain.

### *Divers*

Divers are exposed to various conditions that may contribute to dehydration.[18] Water immersion alone results in diuresis, decreased plasma volume, and increased urinary excretion of sodium, potassium, calcium, and magnesium, particularly when the water is cold.[19] Likewise, hyperbaric conditions in the absence of immersion can cause a hyperbaric diuresis.[20] Moreover, when saturation divers wear hot water suits to maintain body temperature in the cool water, thermal stress may result in additional fluid loss through sweat.[21] This water must be replenished. Importantly, several studies have also indicated that pre-dive oral hydration may reduce the risk of decompression sickness, perhaps by minimizing dehydration and preventing diving-induced hypovolemia.[22,23] Since drinking while diving is problematic, pre-dive and between-dive hydration are the best courses of action.

## Urinary Relief Systems

Hydration has long been known to be important to optimizing human performance. However, for some specialized communities, such as aircrew and divers, urinary relief systems have been a second thought. Operation Enduring Freedom pushed the limits of Navy and Air Force aircrew's physiological limits as flight operations pushed jet aircrew into missions reaching nine hours.[24] Whereas many aircraft have relief tubes, which are easy for men to use, choices are limited for women, which makes the thought of a long mission a painful reminder of the lack of relief systems. One system currently available for women is the Female Urinary Diversion Device (FUDD), which has been tested in women who were deployed to austere locations in support of Operation Enduring Freedom.[25] The results were positive with women reporting it was easy to use, store, and carry.[25] Whether it could be adapted for female pilots and aircrew as a relief system has not been studied. Because dehydration has become a high-profile concern, interest in developing adequate urinary relief systems for both men and women has increased in the United States Air Force and Navy.

Currently, several systems are authorized by the Navy and the Air Force including urine collection bags, funnel systems, diapers, and a collection device that can pump urine into a 1.7-quart collection bag as soon as it is activated by the presence of urine. Although developed for aircrew, they may be suitable for other communities, check with the appropriate program offices for more specifics and for acquisition information.

## Summary

Water is essential for physiological function. Optimal fluid balance is of great importance to Operators as clothing, activity, and environmental conditions place severe demands on the body to maintain fluid balance. Substantial water loss can occur under any number of conditions, directly impacting physical and cognitive performance and ultimately the ability to accomplish the mission. Operators should be conscious of their water loss and develop personalized strategies to ensure adequate hydration before, during, and after physical activity.

### Disclosures

The authors have no financial relationships or conflicts to disclose.

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## Author Contributions

JMS reviewed the literature, drafted, and finalized the manuscript. JRL and PD provided subject matter expertise and critical feedback for the manuscript. All authors have read and agreed to the published version of the manuscript.

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