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Dehydration Presents Unique Risks for Pilots

The effects of water loss can be pronounced for flight crewmembers operating in the dry environment of high altitudes; therefore, crewmembers should ensure that they drink adequate amounts of water and should try to avoid situations that deplete the body's supply of water.

FSF Editorial Staff

Water is the main component of the human body. About two-thirds of body weight is water. A person weighing 170 pounds (77 kilograms) has more than 10 gallons (38 liters) of water in the cells, around the cells and in the bloodstream.

Water is essential for replicating cells, carrying nutrients through the body, eliminating waste products from the body and regulating body temperature.

When water is consumed, it is absorbed from the gastrointestinal tract and leaves the body primarily in the form of urine excreted by the kidneys. The kidneys excrete varying amounts daily, ranging from less than one pint (0.5 liter) to several gallons (one gallon equals about 3.8 liters). Perspiration increases the amount of water lost from the body through evaporation; on hot days or after vigorous exercise, the loss can be substantial.

An excessive loss of water from the body also can result from fever, exposure to hot weather, vomiting, diarrhea, use of diuretics (substances that increase the production and excretion of urine), and diseases such as diabetes mellitus, diabetes insipidus[1] and Addison's disease.[2] The water loss — or decreased water intake — can result in dehydration, which can lead to fatigue, increased susceptibility to physical stressors and changes in performance, said Sarah A. Nunneley, M.D., M.S., of Brooks Air Force Base, Texas, U.S.[3]

"Considering the possibly disastrous consequences of pilot error, the acceptable level of [dehydration and other heat-related medical problems] may be very low," she said.[4]

For example, one captain of an air carrier said, in a report to the U.S. National Aeronautics and Space Administration

Aviation Safety Reporting System,[5] that his first officer had become ill during a transcontinental flight in November 1989. He described the situation as follows:[6]

> Prior to departure, the first officer mentioned that the seafood entrée that he consumed the previous evening was giving him an upset stomach, and he reported some diarrhea. [Several hours later, while the airplane was being flown in cruise flight at 41,000 feet,] the first officer asked to be excused from the cockpit to use the lavatory. As he was leaving the cockpit, I heard a commotion behind me, and a flight attendant … seated on the jump seat started to scream. I turned around just in time to see the first officer falling backward over the flight attendant and a catering beverage insert that was routinely placed on the flight deck. He fell against his seat, where he struck the shoulder harness lock handle. As he slumped sideways across the cockpit, it was my opinion that he was unconscious. …
>
> I grabbed the observer's oxygen mask and … [applied] the mask to the first officer. After about 45 seconds, the first officer regained consciousness. He spent several minutes on the jump seat with oxygen on, and then, for a period of time, he was back and forth to the lavatory because of diarrhea and nausea. My concern now was that I was on my own in a two-man cockpit.

The captain said that the first officer's condition improved and that he returned to his duties just before the descent. After a normal landing, the first officer was taken to the airport medical facility, where authorities determined that he was "very dehydrated," the captain's report said.

"He received two containers of fluid intravenously," the report said. "He then was transferred to a local hospital."

Richard Rinehart, M.D., a U.S. Federal Aviation Administration (FAA) senior aviation medical examiner, said that flying tends to be conducive to dehydration.[7]

"Under normal circumstances, the body will lose three [pints; 1.4 liters)] to four pints [1.9 liters] of water every day from breathing, sweating and urinating," Rinehart said. "Add to these normal functions the effects of being in a pressurized cockpit — which becomes a parched environment within minutes after takeoff — and dehydration may result. And what's the first thing you request after reaching cruise? Coffee, [caffeinated soda] or tea, all of which are diuretics … that will exacerbate the problem."

A pilot is most at risk if he or she is dehydrated at the beginning of a flight. Among the causes of excessive water loss are: consumption of alcoholic beverages, because alcohol's diuretic effects continue even after the blood alcohol level has decreased to zero; drinking coffee or tea, because they have similar diuretic effects; working in the heat before flying, because of the increase in perspiration; and failing to drink enough water.[8]

Don Hudson, M.D., aeromedical adviser to the Air Line Pilots Association, International (ALPA) and director of the ALPA Aeromedical Office, said that, during meetings with pilots, his office emphasizes the risks of dehydration.[9]

He described the environment of the flight deck as "incredibly dry, about 3 [percent] to 5 percent humidity" and said that, although the dryness helps to curb the transmission of disease, it also accelerates the body's loss of water. He said that he tells skeptical pilots to soak a terry-cloth towel in water and to hang the towel, dripping wet, on the flight deck.

"In an hour and a half, it will be bone dry," Hudson said. "The same thing is happening to your body."

Dehydration is "an underrated factor in terms of pilot fatigue," he said. "That's especially true in international flights. When you're dehydrated, it's just another stress factor in performing your job."

The typical recommendation is for a healthy adult to drink about two quarts (1.9 liters) of water a day (see "Recommendations for Preventing Dehydration"). That

Recommendations for Preventing Dehydration

The following are recommendations for preventing dehydration and other heat-related problems:[1]

- Drink about two quarts (1.9 liters) of water every 24 hours. The water should be cool (40 degrees Fahrenheit [4 degrees Celsius]). Drink before you become thirsty, and drink from a container that allows you to measure daily water consumption;
- Limit consumption of alcohol and caffeine. Both are diuretics, which increase the excretion of urine;
- Monitor work and recreational activities, and stop what you are doing if you feel light-headed or dizzy. Exercise can result in water loss that is difficult to overcome quickly;
- Monitor your body's response to aging, illness, fever, diarrhea or vomiting; and,
- Remember that your body's adjustment to a major change in weather, such as the sudden onset of hot weather, can take one week to two weeks.♦

Reference

1. Shaw, Rogers V. II. "Dehydration and the Pilot." *The Federal Air Surgeon's Medical Bulletin* (Spring 2000): 10.

amount usually is enough to replenish the amount excreted in urine and perspiration and enough to prevent decreases in blood volume and in the concentration of blood electrolytes (dissolved mineral salts, including sodium, potassium, calcium, magnesium and phosphates).[10]

The amount of water in the body and the concentration of electrolytes in the blood are closely related, and both must be maintained at proper levels for the human body to function properly. For example, a high concentration of sodium in the blood causes the body to retain water to dilute the sodium; a low concentration of sodium causes the kidneys to excrete more urine to increase the sodium level.

When a person is dehydrated, the concentration of sodium in the blood usually rises. The person becomes thirsty and drinks. If water consumption is not adequate to offset water loss, the kidneys excrete less urine, and perspiration decreases. Some of the water in the body's cells replaces water in the bloodstream, so the cells begin to dry out and to stop functioning properly. The malfunctioning of brain cells can lead to confusion, one of the primary symptoms of severe dehydration. Typically, dehydration results in the loss of electrolytes as well as the loss of water, and the depletion of electrolytes slows the movement of water from the cells into the blood.

Table 1 shows that thirst typically is the first symptom of dehydration; thirst may not become apparent until so much water has been eliminated from the body that an individual has lost about 2 percent of body weight.[11] Subsequent symptoms, which may become apparent after loss of about 5 percent of body weight, include fatigue, nausea and emotional instability. As dehydration worsens, symptoms may include headache, elevated body temperature, elevated pulse, elevated respiratory rate, dizziness, slurred speech, weakness, delirium, swollen tongue, circulatory problems, inability to swallow, and kidney failure.

Table 1
Symptoms of Dehydration

Amount of Water Lost	Symptoms
1.5 liters (1.4 quarts)	Thirst
3 liters (2.8 quarts)	Sluggishness, fatigue, nausea, emotional instability
4 liters (3.8 quarts)	Clumsiness, headache, elevated body temperature, elevated pulse, elevated respiratory rate
5 liters (4.7 quarts)	Dizziness, slurred speech, weakness, confusion
6 liters (5.7 quarts)	Delirium, swollen tongue, circulatory problems, decreased blood volume, kidney failure
9 liters (8.5 quarts)	Inability to swallow, painful urination, cracked skin
12 liters (11.3 quarts)	Imminent death

Source: Maidment, Graeme. "Chapter 15: Thermal physiology." In *Aviation Medicine, third edition,* edited by Ernsting, John; Nicholson, Anthony N.; Rainford, David J. Oxford, England: Butterworth Heinemann, 1999.

Mild instances of dehydration can be resolved by drinking water. If electrolytes — especially sodium and potassium — have been depleted, they must be replaced. Commercially available drinks have been formulated to replace electrolytes lost during exercise, but other non-caffeinated liquids are equally effective when they are consumed with salt.[12]

One Australian student pilot wrote about a flight from Darwin during which he experienced several of the symptoms of dehydration:[13]

> I was having difficulty doing anything beyond simply flying the aircraft. … Over the next 10 minutes, the situation deteriorated. … I didn't realize it at first, but my peripheral vision was reducing quite quickly, almost as if two dark curtains were being drawn on each side of my head until I could only see straight ahead in a very limited arc.

He said that, when he finally realized that he was hot, sweating heavily and probably should feel thirsty, he grabbed a water bottle, drank about one liter (one quart) of water and almost immediately noticed a change.

"Within five [minutes], the curtains were drawn back as if by magic — my peripheral vision returned and logical thinking with it," he said.

David Newman, MBBS (bachelor of medicine and bachelor of surgery), formerly the chief instructor at the Royal Australian Air Force Institute of Aviation Medicine, said that the pilot had experienced "a high level of dehydration."[14]

Newman said that the pilot's loss of peripheral vision was a "warning that, unless something happens to prevent it, loss of consciousness will soon occur." He said that dehydration had reduced the pilot's total blood volume and that, as a result, his brain probably was not receiving the proper amount of blood and oxygen.

"Fortunately for this pilot, he realized what was going on, probably just in time," Newman said.

Dehydration often is associated with heat exhaustion, a medical problem that results from exposure to hot weather. Heat exhaustion occurs in three stages.[15]

The first, and mildest, stage of heat exhaustion is heat stress, in which body temperature increases to between 99.5 degrees and 100 degrees Fahrenheit ([F]; 37.5 degrees and 37.8 degrees Celsius [C]). Other symptoms include decreases in performance, coordination, decision-making ability, alertness, visual capability, caution and caring.

Heat stress can progress to heat exhaustion, in which body temperature is from 101 degrees to 105 degrees F (38.3 degrees to 40.6 degrees C). Symptoms include fatigue, nausea and/or vomiting, giddiness, cramps, rapid breathing and loss of consciousness.

The most extreme stage is heat stroke, a life-threatening condition in which the body temperature rises above 105 degrees F and the body's heat-control mechanism no longer functions. Symptoms include confusion, disorientation, bizarre behavior and coma.

Failure to drink enough water may contribute to the formation of kidney stones, which are stonelike masses that can form anywhere in the urinary tract.

Kidney stones may form because the urine has too great a concentration of the types of mineral salts responsible for stone formation (one of the consequences of dehydration) or because the urine lacks substances that inhibit stone formation. Kidney stones vary in size and can be too small to be seen with the unaided eye or as large as one inch (2.5 centimeters) or more in diameter.

Small kidney stones may cause no symptoms. Larger kidney stones may cause severe pain in the lower abdomen; the pain sometimes radiates to the genital area. Other symptoms may include nausea, vomiting, a distended abdomen, chills, fever and blood in the urine.

Various options exist for treatment of kidney stones, including an increase in fluid intake in an attempt to flush the stone out of the urinary system; extracorporal shock wave lithotripsy, in which ultrasound waves break the stone into smaller pieces that can pass through the urinary system; percutaneous nephrolithostomy, in which the stone is removed through an incision; and ureteroscopic stone removal, in which the stone is removed by a small flexible tube inserted through the urethra and the bladder.

Formation of kidney stones generally can be prevented by drinking adequate amounts of water, said Quay C. Snyder, M.D., associate aeromedical adviser to ALPA.[16]

"The dry environment of the pressurized aircraft cabin leads to dehydration," Snyder said. "A lack of a ready source of fluids and an unwillingness to leave the cockpit frequently to 'attend to physiologic needs' during long flights also puts the pilot at increased risk for dehydration and stone formation. The commuter pilot who has little time between flights, often sits on a hot ramp and has physical work to perform associated with the flight may also become dehydrated. The general aviation pilot on a long cross-country flight without enough water on board is also at risk. … A good rule … for adequate hydration is to drink enough to keep the urine clear. Pilots with previous kidney stones rarely forget this rule."

American Airlines Capt. George Shanks is one of those pilots. Shanks wrote in the airline's *Flight Deck* magazine about the "agony" of his kidney stone. The pain began one night as an ache in his lower left side and gradually increased in intensity, he said.[17]

"I tried everything I could think of to relieve the pain," he said. "Nothing worked."

The next day, he observed blood in his urine and went to a hospital emergency room, where the kidney stone was diagnosed.

The kidney stone probably could have been avoided, Shanks said.

"I will explain the error of my ways," he said. "I fly international. Long flights. I don't drink enough water. I sit for long periods of time without getting out of the seat to stretch my legs and relieve myself. … I brought this on myself."

Many regulatory authorities, in accordance with recommendations of the International Civil Aviation Organization (ICAO), require that a diagnosis of a kidney stone generally disqualifies a pilot from medical certification; after the stone has been eliminated, the pilot again qualifies for medical certification. The ICAO *Manual of Civil Aviation Medicine* says that an applicant for medical certification who has had one experience with a kidney stone "may be considered medically fit for aviation duties when completely free of symptoms and evidence of underlying pathology."[18]

Recurrent kidney stones, however, "should be regarded with considerably more suspicion and should generally be disqualifying for aviation duties," the manual says. Nevertheless, the manual says that medical certification may be granted with limitations, such as a requirement that the pilot fly "as or with copilot" and that he or she undergo frequent urological tests.

Dehydration can present flight crewmembers with serious medical risks. Nevertheless, otherwise healthy crewmembers generally can prevent dehydration by drinking adequate amounts of water and by avoiding or counteracting situations that deplete the body's supply of water.♦

References and Notes

1. Diabetes mellitus is a disorder in which the body fails to use insulin adequately, resulting in abnormally high blood levels of glucose. Diabetes insipidus is a disorder in which the body produces insufficient amounts of antidiuretic hormone. Both disorders may result in excessive urine production.

2. Addison's disease, also known as chronic adrenal insufficiency or hypercortisolism, is a disorder that occurs when the adrenal glands do not produce enough of the hormone cortisol. The disorder causes a person to urinate excessively and become dehydrated.

3. Nunneley, Sarah A. "Chapter 12: Thermal Stress." In *Fundamentals of Aerospace Medicine, second edition*, edited by DeHart, Roy L. Baltimore, Maryland, U.S.: Williams & Wilkins, 1996. 411.

4. Ibid., 411.

5. The U.S. National Aeronautics and Space Administration (NASA) Aviation Safety Reporting System (ASRS) is a confidential incident-reporting system. The ASRS Program Overview said, "Pilots, air traffic controllers, flight attendants, mechanics, ground personnel and others involved in aviation operations submit reports to the ASRS when they are involved in, or observe, an incident or situation in which aviation safety was compromised. … ASRS de-identifies reports before entering them into the incident ASRS database. All personal and organizational names are removed. Dates, times, and related information, which could be used to infer an identity, are either generalized or eliminated."

   ASRS acknowledges that its data have certain limitations. ASRS *Directline* (December 1998) said, "Reporters to ASRS may introduce biases that result from a greater tendency to report serious events than minor ones; from organizational and geographic influences; and from many other factors. All of these potential influences reduce the confidence that can be attached to statistical findings based on ASRS data. However, the proportions of consistently reported incidents to ASRS, such as altitude deviations, have been remarkably stable over many years. Therefore, users of ASRS may presume that incident reports drawn from a time interval of several or more years will reflect patterns that are broadly representative of the total universe of aviation-safety incidents of that type."

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8. Ibid.

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16. Snyder, Quay. "Aeromedical Report: Kidney Stones." *Air Line Pilot* Volume 70 (February 2001): 5–7.

17. Shanks, George. "Getting Stoned Is Not as Much Fun as It Sounds: Kidney Stones and Long-haul Flying." *American Airlines Flight Deck* (January–February 1998): 13–15.

18. International Civil Aviation Organization. *Manual of Civil Aviation Medicine.* (Montreal, Quebec, Canada, 1985), III-6-2.

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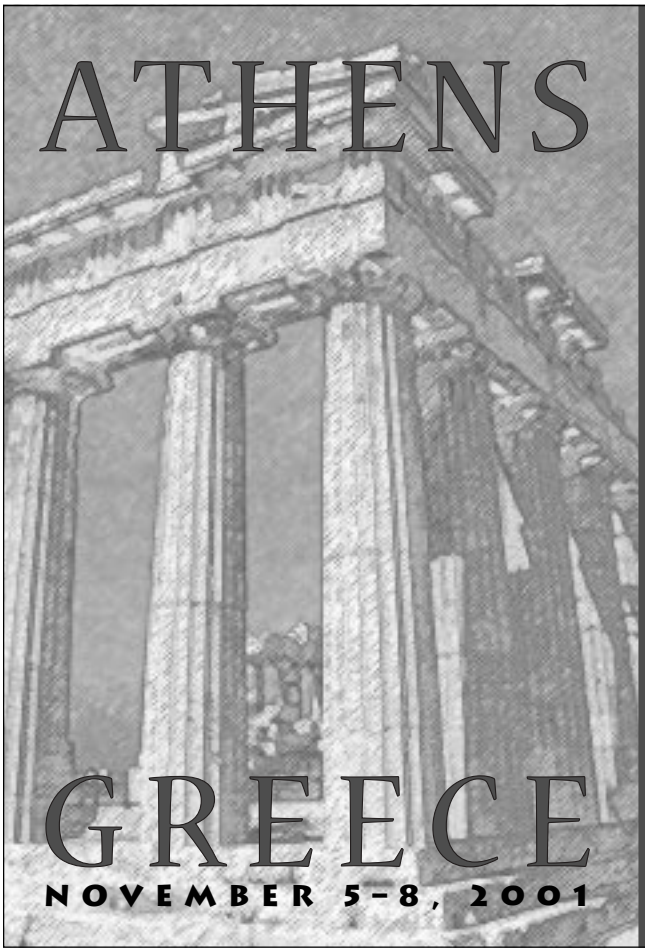

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