# Dehydration…You Don't Want to Go There!

By
Edward H. Nessel, R.Ph, M.S., MPH, PharmD.

If you find yourself in a state of ***dehydration***, you made a mistake. Whether you are preparing for intense competition, trying to maintain a sustainable physiology during vigorous training, or partaking in the inevitable all-important recovery…if there simply is not enough liquid bathing the ***internal*** environment of the body, then impaired performance and delayed and/or poor recovery will mostly be what we see. And diminished physical performance is not the only possibility. Mental acuity can be compromised in a dehydrated state. Most "civilians" walk about day-to-day in a state of at least partial dehydration (and not able to be at their best) only to become aware that something is not right when challenged physically with intermittent vigorous exercise. A serious athlete in a state of dehydration, as stated above, made a mistake, and it should not be taken lightly. One of the "dictums" of physiology is to "***drink before you are thirsty and after you are not***." Relying on the body's thirst mechanism is fool's play at best. In fact, the older one gets, the less reliable the ***thirst alert*** becomes. In much of the population (almost 40%) the thirst mechanism is so weak that it is often mistaken for hunger.

There are several seemingly sophisticated preparations available to athletes today, either already in liquid form or in need of water to make the correct mix. Many serve the purpose, or at least claim to, of fueling the muscles, or providing a recovery environment for "spent" or damaged muscles, or replenishing what has been lost electrolyte-wise due to the body's heat-dissipation mechanism of sweating. ***But the single most important element needed to make any of these preparations work is water.***

It may seem ironic that ***swimmers***, literally "bathing" in water throughout their in-pool training, ***can become dehydrated***. ***Swimmers sweat like any other athlete*** training vigorously; it just can't be noticed in water. Ask any swimmer who forgets his/her drinking bottle to practice how the mouth soon feels like a bed of cotton. And this is made worse if the ambient air and water temp are allowed to rise to where heat is no longer able to be dissipated from the body moment-to-moment or with outdoor swimming in a cooler, but less humid atmosphere which only serves to hasten the drying effect of inhaled air.

***Water is second only to oxygen in importance to life.*** A young healthy ***male's total body weight is about 60% water***; that of a young ***woman's is about 50%.*** We can survive loses of up to 40% of our body weight in fat, carbohydrate, and protein; but a ***water loss of only 9% to 12% of total body weight can be fatal.*** Approximately ***two thirds of the water in our bodies is contained inside our cells (intracellular fluid) bathing necessary cellular elements with substances that sustain life. The remainder is outside the cells (extracellular fluid) performing tasks of transporting fuel and waste to and from metabolism-oriented structures.***

### *Water Balance during Exercise*

Water plays several critical roles in exercise, mostly related to the blood's capacity to carry various elements (oxygen, glucose, fatty acids and amino acids, carbon dioxide and other metabolic wastes) to and from functioning cells of all the organs. ***Water also plays a large role in heat dissipation from exercising muscles and the maintaining of blood pressure and cardiovascular functioning during physiologically stressful moments.*** .

An interesting relationship occurs when the body is forced to handle vigorous exercise. ***Metabolic oxidation occurring during muscular contractions actually produces water as a physiologic by-product.*** The more muscular contraction, the more water produced ***but this is still only a fraction (maybe a tenth) of the water lost through other means:*** evaporation through the skin, evaporation through the body's action of moisturizing inhaled and exhaled air, excretion from the kidneys and the large intestine. At rest the kidneys excrete about two ounces (60 mls) of water per hour. You might think the kidneys would excrete more as the metabolic rate increases; well, they can for a while, but only to a point. Then ***the production of urine goes way down when the body senses that fluid loss is occurring too rapidly to keep the body in a steady hydrated state.***
***is not reversed.*** How likely is the condition to occur?

### *Hyponatremia*

There has come to light within the past few years the somewhat rare condition of ***hyponatremia***. Though it should not occur in swimmers, in the spirit of complete presentation, this condition is discussed as a serious form of dehydration that potentially could arise in a swim-related event. In those competing in triathlons where the grueling distance run is saved for last, after the swim and then the bike legs, those who place themselves in the circumstance of potentially creating this condition can, at best, expect a poor finishing performance, and, at worst, place the body in physiologic peril. No argument that fluid replacement is desirable, but can too much of a good thing be bad? In the recent past, several cases of ***hyponatremia*** have been reported in endurance athletes, though ***all land-based***. This condition is clinically defined as a blood-sodium concentration below the normal range of 136 to 143 mmoles/liter. ***Symptoms*** would logically appear in stages: ***weakness, disorientation, seizures, and coma if the condition is not corrected quickly.***

The processes that regulate fluid volumes and electrolyte concentrations are normally highly effective, so consuming enough water to dilute plasma electrolytes to dangerously low levels is difficult under most circumstances. Distance runners who log between 15 and 25 miles per training session in warm weather and who do not salt their food excessively don't usually develop electrolyte deficiencies. Even those marathoners who lose three to five liters of sweat and drink two to three liters of water usually will maintain normal plasma concentrations of sodium, chloride, and potassium. (1)

Tackling distances greater than the marathon (ultra marathon, etc) can obviously tax the physiology to extents that push all boundaries to their very thin limits. But a study done in 1991 by Barr and colleagues showed that when subjects consumed more than seven liters of plain water during six hours of exercise in the heat, their plasma sodium concentration decreased only negligibly by about 3.9mmmoles/liter. (2)

The ideal solution to prevent hyponatremia would be to replace water at the exact rate that it is being lost or to add sodium to the ingested fluid to keep homeostasis. The problem with the latter approach is that sports drinks that have somewhat of a palatable taste contain only mild to moderate amounts of sodium concentration. So their consumption is more for energy and rehydration than pure sodium replacement. And taste is a very important element in the manufacture and marketing of sports drinks since palatability can change before, during, and after intense activity.

I would have to add the scenario that if an athlete, choosing to "push the physiologic envelop," happens to be on medication that can affect the immediate internal environment, for example, with diuretics, consequences not normally considered, are at risk of appearing.

### *Dehydration and Exercise Performance*

***Even minimal changes in the body's water content can impair muscular contraction to the point where the swimmer feels "heavy" and slow in the water…like he or she is moving through thick syrup rather than smooth-flowing water.*** The ***muscle fibers*** (myofibrils) ***will be rubbing against each other creating excess frictional heat in addition to the metabolic heat that is expected.*** Like a piston in an automobile engine that seizes due to lack of oil for lubrication, ***muscle fibers will go into spasm, and power production will be reduced noticeably.*** Many studies have shown that dehydrated athletes are intolerant to prolonged (greater than 60 minutes) vigorous exercise and heat stress. The heat stress factor is mollified somewhat by the immediate water environment of the swimmer, water having a much better heat-drawing capacity than air. But as intensity of training increases, so do the effects of internal heat production, and ***even an immersed vigorously-training swimmer will dehydrate and suffer during an intense practice session.***

***The impact of dehydration on the cardiovascular and heat-regulatory systems is quite predictable. Fluid loss decreases plasma volume; this, in turn, decreases blood pressure, which then reduces blood flow to the muscles and skin. In an effort to deal with all this, heart rate increases. Because less blood reaches the skin overall, heat dissipation is hindered, and the body retains more heat in areas with a lot of muscle activity*** (we quite often see a flushing effect on the upper back of swimmers). ***As dehydration approaches 2% of total body weight, both heart rate and body temperature are elevated during exercise. If the water loss reaches 4% or 5% of body weight, say with land-based activity, the capacity for prolonged aerobic effort declines by 20% to 30%.***

In athletic endeavors that require a mix of aerobic and anaerobic or more anaerobic activity (under 3 minutes…which covers most swimming events), the drop off in performance is not as dramatic but it is certainly there; especially if multiple events are swum over a relatively short period of time. Enough of a drop is seen such that the resultant effort can be diminished in close competition.

Below is a listing of physiologic parameters that show negative responses to dehydration; most are **not quickly improved,** if at all, when rehydration is attempted, which reinforces the dictum of prevention of dehydration is much better than correcting it…

***Alteration in Physiological Function and Performance Due to Dehydration*** (2)

| Physiology | Dehydration | Rehyration |
|---|---|---|
| **Cardiovascular** | | |
| **Blood volume/plasma volume** | **diminished** | **delayed response** |
| **Cardiac output** | **diminished** | **delayed response** |
| **Stroke volume** | **diminished** | **delayed response** |
| **Heart rate** | **diminished** | **delayed response** |
| **Metabolic** | | |
| **Aerobic capacity (VO2Max)** | **somewhat diminished** | **same** |
| **Anaerobic power** | **somewhat diminished** | **same** |
| **Anaerobic capacity** | **somewhat diminished** | **same** |
| **Blood lactate, peak value** | **diminished** | **diminished** |
| **Buffer capacity of blood** | **diminished** | **delayed response** |
| **Lactate threshold** | **diminished** | **delayed response** |
| **Muscle & liver glycogen** | **diminished** | **diminished** |
| **Thermoregulation & fluid balance** | | |
| **Electrolytes in muscle and blood** | **diminished** | **no change** |
| **Exercise core temperature** | **increased** | **delayed cool down** |
| **Sweat rate** | **diminished** | **delayed response** |
| **Skin blood flow** | **diminished** | **delayed response** |
| **Performance** | | |
| **Muscular strength** | **slightly diminished** | **slightly diminished** |
| **Muscular endurance** | **diminished** | **diminished** |
| **Muscular power** | **slightly diminished** | **slightly diminished** |
| **Muscle movement to exhaustion** | **diminished** | **delayed response** |
| **Total work performed** | **diminished** | **diminished** |

## *Electrolyte Loss during Exercise*

In addition to body water lost during vigorous exercise, many nutrients, especially minerals, escape with sweat. We stated above, swimmers don't sweat as much as land-based athletes, but they do sweat, and they do lose body water. Sweat is a filtrate of blood plasma; it contains many substances found there including sodium ($Na^+$), chloride ($Cl^-$), potassium ($K^+$), magnesium ($Mg^{++}$), and calcium ($Ca^{++}$). It is mostly water (99%) but contains enough lost electrolytes to produce altered physiologic responses in some athletes. What happens next is the body's sensing this loss and causing the kidneys to greatly shut down urine production; in effect, to hold on to body fluid. ***An additional response also causes the kidneys to produce a powerful hormone called <u>aldosterone.</u> This acts to make the kidneys retain sodium and chloride ions*** (Na Cl…salt). What follows is ***the amount of these ions rises and produces an increased concentration that signals the brain's hypothalamus to produce the <u>thirst alert</u>*** so we would increase our water intake. This dilutes them back to normal. Unfortunately, all this takes time…***<u>it is not an immediate response</u>***, which affords a delayed effect of recovery. Someone in the middle of vigorous training or competition that develops a healthy thirst has entered the ***"zone of metabolic distress"***, and his or her ***performance will most likely be compromised.*** The damage is done, so to speak, though some effort can be salvaged if rehydration is done quickly and thoroughly.

***If left to normal physiologic recovery, up to 48 hours may be needed for electrolyte and fluid rebalancing.*** This is an unacceptable time delay for those needing to partake in regularly-scheduled daily training regimens. This is where the commercial "***recovery drinks"*** probably have a place. Though they do provide for moderate energy-replacement to the musculature (and are touted as such) due to the mild glucose-complex content, as mentioned above, ***they also have enough salt in them, among other things, to actually create a slight thirst, making the desire to drink more prominent which then helps to ensure adequate rehydration.*** Gatorade at 110mg of sodium per 8 fl ounces has twice the content of Powerade at 55mg per glass.

The author uses a 50-50 mix of red grape juice and Powerade in his daily travails back and forth across the pool: grape juice to help with circulation (from resveratrol in the grapes) and Powerade, with its better carbohydrate formulation, for energy and rehydration. A caution here is for those who have difficulty handling fructose which is in the grape juice.

***Take Home Points to Remember:***

***(1) Our immediate need to replace lost body fluid is greater than our need to replace lost electrolytes or anything else consumed during vigorous exercise.***

***(2) Since our thirst mechanism does not exactly match our hydration state, we should "drink before we are thirsty, and after we are not."***

***(3) Adequate fluid and energy intake during vigorous training with appropriate timing for competition reduces the risk of dehydration and energy depletion and optimizes the body's cardiovascular and thermoregulatory functions which should eliminate two major causes of diminished performances.***

***References***

***(1) Barr, S.I., Costill, D.L., Fink, W.J., & Thomas, R. (1991). Effect of increased training volume on blood lipids and lipoproteins in male collegiate swimmers. Medicine and Science in Sports and Exercise, 23, pp.795-800.***

***(2) Wilmore, Jack, & Costill, David, Physiology of Sport and Exercise, 2nd Edition, 1999; pp. 469-484.***