HYDRATION FOR ENDURANCE ATHLETES

USA

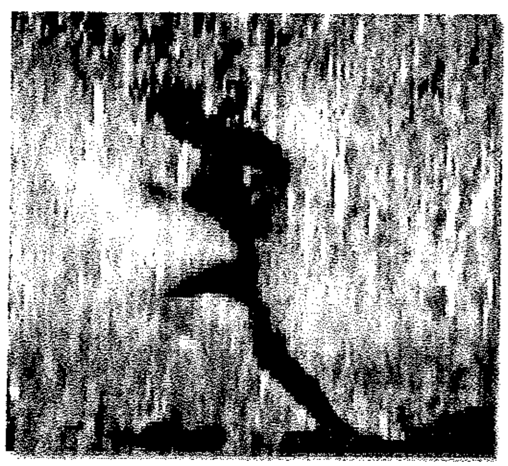

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TABLE OF CONTENTS

HYDRATION IN ENDURANCE ATHLETES

PURPOSE

Sustaining proper hydration for athletic reasons is one of the easiest and most important nutritional routines for optimizing performance and injury prevention, yet many athletes have inadequate hydration practices. In fact, even a slight degree of dehydration (2% loss of body mass due to fluid loss) can adversely affect performance.

The subject of hydration is not well understood in the general public. This may be due to knowledge that is based on anecdotal evidence. Undoubtedly these dubious claims quickly become common knowledge among athletes and coaches alike.

The purpose of this handout is to eliminate many of the myths concerning proper and improper hydration as well as provide the coach and endurance athlete with a concrete reference on the risks of improper hydration and benefits of hydrating properly.

The "bottom line" of this paper is found in the Recommendations for Proper Hydration section on page 18. Here you can find the position stands from USA Track and Field, Association of International Marathons, National Athletic Trainers Association and the American College of Sports Medicine. Athletes and coaches may want to read that section first, and then review the other sections for important supportive information.

INTRODUCTION

Water

Water is by far the largest single component of the body, constituting 45-75% of total body mass, depending on age, gender and fitness.

Because adipose (fat) tissue contains almost no water, fat people have a smaller proportion of water than do lean people. Lean adult males have a proportion of water of about 60% total body mass. In contrast, lean adult females, on average, have more subcutaneous fat than do males; therefore they have a slightly lower proportion (55% of body mass) of body water. It should be noted that these proportions are averages taken from a sample of the general population, and the proportions of water to body mass may be slightly greater in the endurance athlete.

Fluid Intake and Loss

The body can acquire water in two ways: *ingestion* and *metabolic synthesis*.

- The main sources of body water are ingested liquids (1600 ml/d; average adult) and moist foods (700 ml/d; average adult) absorbed from the gastrointestinal tract.
- Metabolic synthesis produces water in the body when electrons are accepted by oxygen during aerobic cellular respiration (200 ml/d; average adult).
- Therefore in the **average adult**, daily water gains total approximately 2500 ml and may be higher in the endurance athlete.

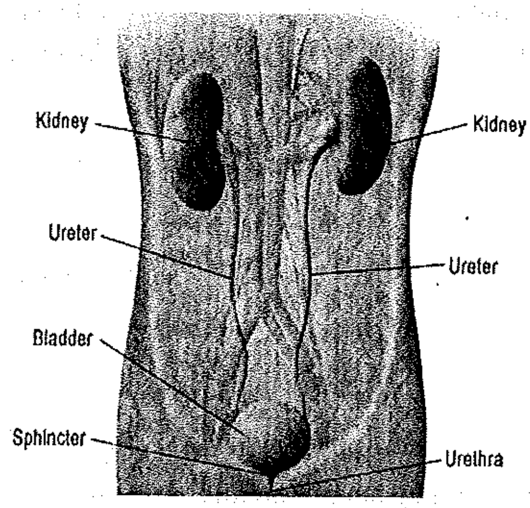
The rate of formation of metabolic water is not regulated to maintain homeostasis of body water. Instead, metabolic water volume is primarily a function of the level of aerobic cellular respiration, which reflects the level of demand for ATP in body cells. Body water gain is regulated principally by adjusting the volume of water intake. An area in the brain known as the *thirst center* governs the urge to drink.

To say that the body is in *fluid balance* means that the required amounts of water and solutes are present and are correctly proportioned among the various compartments. In homeostasis, water loss equals water gain, so body fluid volume remains constant. Daily water loss occurs through four avenues: *urine production* (1500 ml), *perspiration* (600 ml), *respiration* (300 ml exhaled as water vapor) and *excretion* (100 ml in feces). In women of reproductive age, menstrual flow is another avenue for water loss. The amount of water loss through each avenue can vary considerably. For example, water may literally pour from the skin as sweat during strenuous exercise; or water may also be lost in diarrhea during a GI tract infection.

A BRIEF OVERVIEW: PHYSIOLOGY OF THE KIDNEY

To begin with the basics, *nephrology* is the scientific study of the anatomy, physiology and pathology of the kidney (Figure 1). A *nephron* is the functional unit of a kidney (Figures 2 and 3). The word *renal* also refers to the kidney.

Figure 1. The Urinary Tract



The overall function of the kidney is to regulate extracellular fluid (plasma and tissue fluid) in the body. This is accomplished through the formation of urine, which is a filtrate of plasma.

The formation of urine serves several functions:

- Regulation of the volume of blood plasma
- Regulation of the concentration of waste products in the blood
- Regulation of the concentration of electrolytes in plasma
- Regulation of the acid-base balance of plasma

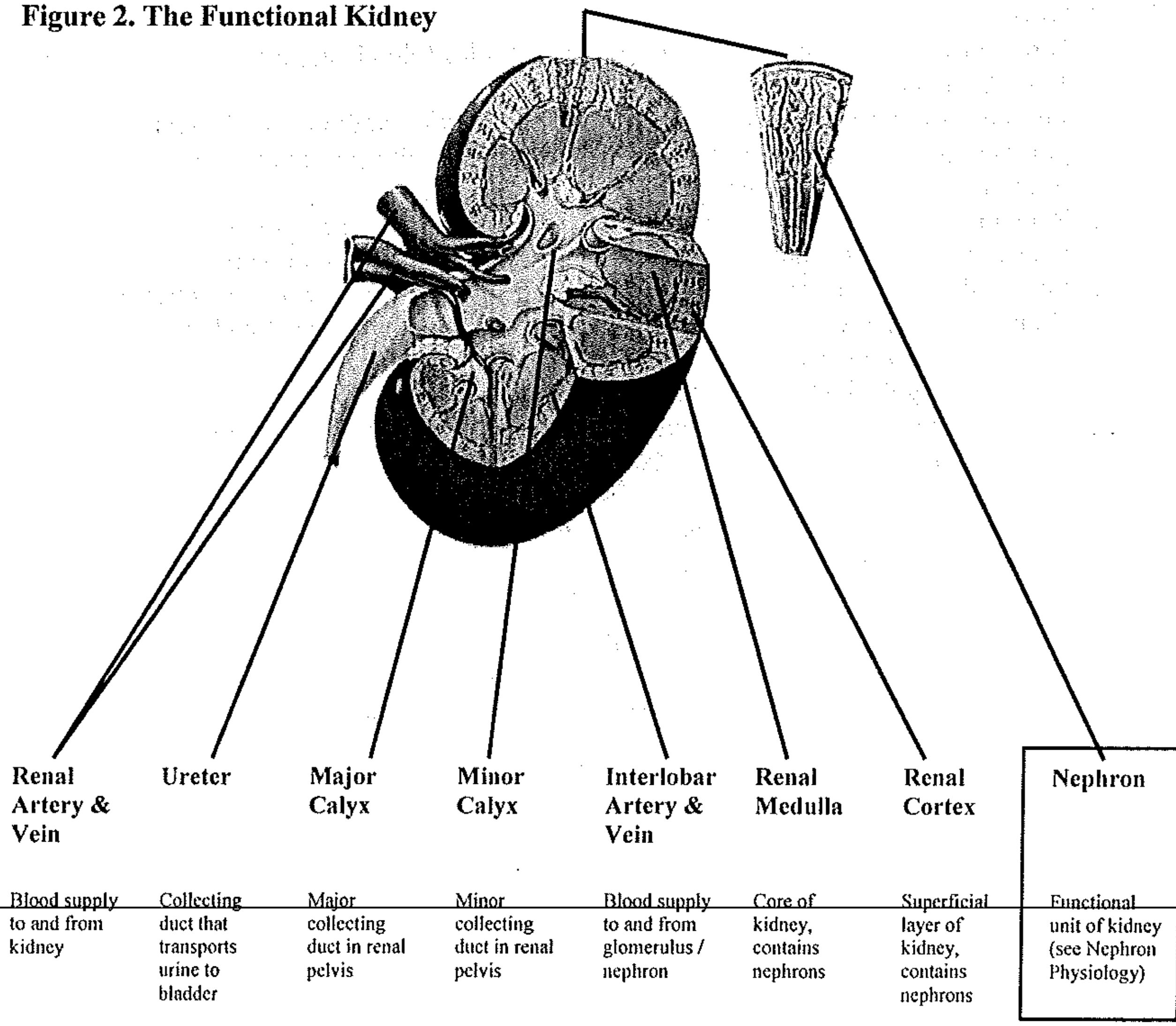
How does the kidney form urine?

The body takes nutrients from food and converts them to energy. After the body has taken the food that it needs, waste products are left behind in the bowel and in the blood.

The urinary system keeps the chemicals and water in balance by removing a type of waste, called *urea*, from the blood. Urea is produced when foods containing protein, such as meat, poultry, and certain vegetables, are broken down in the body. Urea is carried in the bloodstream to the kidneys.

The kidneys remove urea from the blood through tiny filtering units called nephrons (Figures 2 and 3). Urea, together with water and other waste substances, forms the urine as it passes through the nephrons and down the renal tubules of the kidney. The formation of urine is oversimplified for the sake of this handout; however it is noteworthy to understand that the formation of urine is a very complex and detailed task.

Figure 2. The Functional Kidney



Nephron Physiology

Nephrons are the homeostatic functional unit of the kidney and are responsible for the formation of urine. Each kidney contains more than one million of the microscopic nephrons. They exist in the renal medulla and the renal cortex and can also exist simultaneously in the medulla and cortex.

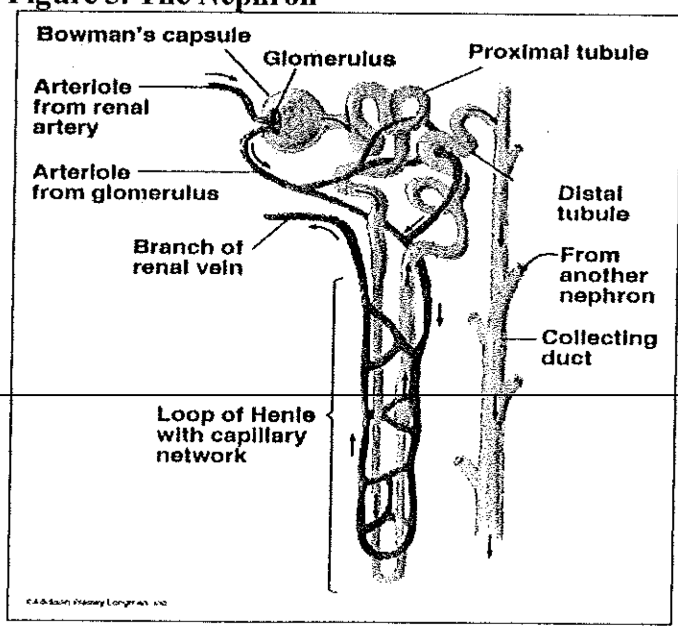
Each nephron consists of a ball formed of small blood capillaries, called a glomerulus, and a small tube called a renal tubule (Figure 3).

The nephron tubule is divided into several different segments. As filtrate flows through the nephron tubule, the contents of the filtrate (water, salt, amino acids, and carbohydrates) are both pulled out of the nephron and separated for use by the body, or they are retained in the nephron for later removal from the body via urine. The pathway of filtrate through the nephron (Figure 3) is as follows:

1. Blood flows into the *glomerulus* from the arterioles (blood supply) and filtrate is filtered from the blood
2. Filtrate flows through the *proximal convoluted tubule*. Sodium, water, amino acids, and glucose are actively transported through the wall of the proximal convoluted tube and back into the interstitial tissue of the kidney.
3. Remaining filtrate flows down the *descending limb* of the *loop of Henle*. Water is transported out of the nephron and into the interstitial tissue of the kidney.
4. Filtrate then flows up the *ascending limb* of the loop of Henle. Sodium is transported into the interstitial space and creates a balanced environment with the already present water.
5. *Collecting duct* collects the remaining filtrate that consists of the components that were not needed by the body and will be removed via urine.

Essentially, nutrients flow through the nephron. Along the way, salts, carbohydrates, and water pass through and are either excreted, or transported back to the blood stream if needed.

Figure 3. The Nephron



Diuretics

Diuretics are substances and hormones that increase the volume of urine excreted. Diuretics:

- directly lower blood volume (and therefore blood pressure)
- decrease the tissue fluid volume
- increase the concentration, and therefore pressure, of plasma within blood capillaries

Diuretics do all of these by increasing the proportion of the filtrate that is excreted as urine and by acting on the nephrons' ability to reabsorb water and/or sodium chloride (salt).

Diuretics are found in several food sources. Caffeine is a diuretic and any caffeinated beverage such as coffee, tea or soda may increase urinary output. Alcohol is also a diuretic. Unless you are taking a diuretic prescribed by a physician, diuretics should be avoided by the endurance athlete because they may cause dehydration.

PHYSIOLOGICAL IMPACTS OF IMPROPER HYDRATION

Endurance athletes may be more susceptible to *dehydration* (fluid loss during exercise), *hypohydration* (fluid loss prior to exercise), and *hyponatremia,* particularly endurance athletes who compete at longer distances (Barr 1999). At rest, under neutral thermal conditions, body fluid balance is maintained at ±0.2% of total body weight. Even a minor imbalance in this homeostatic environment can lead to a decrease in athletic performance. In severe cases, dehydration and hyponatremia can cause permanent damage and/or death.

Under homeostatic conditions, interstitial and intracellular fluids have the same water and salt concentration *(osmolarity)* and they do not shrink nor swell because water intake equals water loss. When the osmolarity between interstitial and intracellular fluids becomes imbalanced, the isotonic environment develops into an unequal balance called either *hypertonic* or *hypotonic.* These imbalanced conditions cause either a shrinkage of cells due to water being "pulled" out of the cell (increase in osmolarity of interstitial fluid = hypertonic) or this can cause the cells to take on excess water and swell (decrease in the osmolarity of interstitial fluid = hypotonic). Changes in osmolarity most often result from changes in the concentration of sodium (Na^+), because "water follows salt".

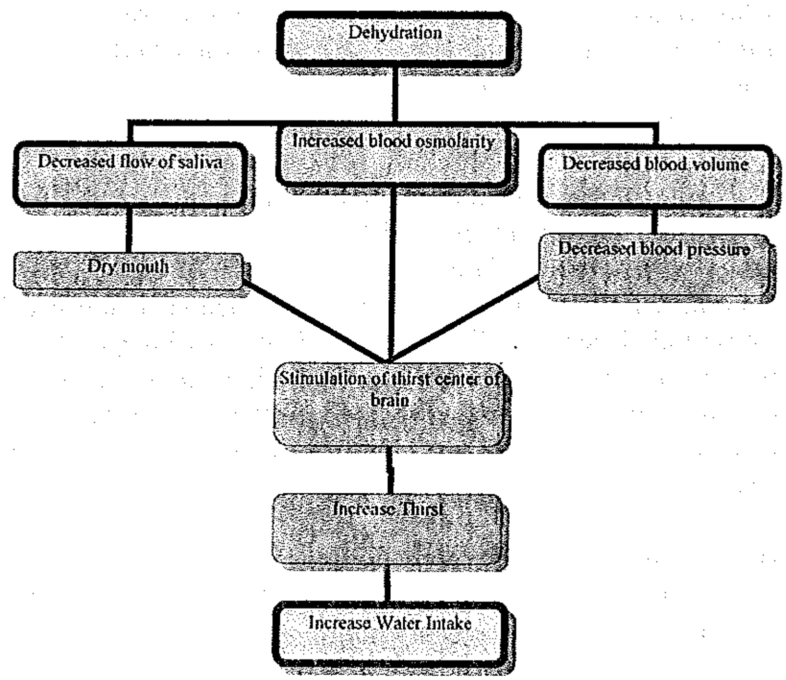
Dehydration

All endurance athletes know what dehydration is because they have experienced it at some point in their athletic careers. Dehydration occurs when water loss is greater than water gain, thus the osmolarity of the body fluids is increased and volume is decreased (Figure 4). Blood volume is also decreased, therefore blood pressure is decreased. When this occurs, receptors called baroreceptors, located on arteries, sense the decrease in blood pressure and send a signal to the thirst center in the brain. Dryness in the mouth is also another trigger for the thirst center to increase thirst. Sometimes, however, either the sensation of thirst does not occur quickly enough, or the access to water is restricted and more severe dehydration occurs. Strangely, thirst driven water ingestion only accounts for a small percentage of daily fluid intakes. Most of the daily fluid consumption is a product of spontaneous eating and drinking (Murray and Dunford 2006).

The total volume of fluid loss from the body is determined by the environmental conditions, size of the athlete, the athlete's metabolic rate, sport, sweat loss, and diet. Most athletes, however, will lose between 1 and 3 liters of sweat per hour of exercise. In response to this, properly functioning kidneys decrease urine production to conserve body fluids.

Human sweat contains small amounts of dozens of organic and inorganic substances (amino acids, urea, lactic acid, calcium, magnesium, iron). In most individuals, sweat loss is not profound enough to warrant an imbalance in minerals like iron, calcium and magnesium. However, in endurance athletes and in some female athletes of non-endurance sports, this inequity may pose a greater dietary challenge to the athlete. For example, a female athlete may lose up to 120 to 360 mg of calcium daily in sweat, which can easily be replaced by drinking a cup of milk. An increased calcium intake for both male and female endurance athletes is recommended. Clinical trials have also reported that athletes lose between 0.039 mg of iron (at rest) and 0.08 mg of iron from sweat, during the first hour of exercise (Waller and Haymes 1996). Men also lost more sweat than women and therefore lost more iron (0.09 mg) in sweat than did women (0.04 mg) (Waller and Haymes 1996).

Figure 4. Dehydration Pathways



Electrolytes are also lost in urine and sweat. The most important electrolytes are sodium (Na^+), potassium (K^+) and chloride (Cl^-). Electrolytes serve several important physiological functions. They are responsible for maintaining proper "fluid balance" within various water-dependent tissues and organs of the body. In addition the movement of electrolytes across the membranes of nerve cells provides the electrical impulse (action potential) that ultimately triggers skeletal muscle and cardiac muscle contraction. Athletes lose a great deal of sweat on a daily basis and consequently may lose a significant amount of electrolytes. The concentration of electrolytes across cell membranes must be strictly regulated to guarantee proper function of cells throughout the body. Although the kidneys are designed to maintain electrolyte balance by storing or removing minerals such as sodium, chloride, potassium, calcium and magnesium; repeated profuse sweating can result in substantial electrolyte loss, especially sodium and chloride, which are the most abundant minerals lost in sweat. If this loss of minerals is not replaced adequately, cramping and hyponatremia may occur.

Endurance athletes often require a large volume of salt intake in order to adequately replace sodium and chloride losses in sweat. The 2004 Dietary Reference Intake recommendations show that North Americans should restrict their daily sodium intake to only 1.5 grams per day. The reason for this recommendation is to prevent hypertension rates in Americans and Canadians. These dietary recommendations may be inadequate for endurance athletes, because endurance athletes lose considerably more salt in their sweat.

Laboratory studies conducted by Montain et al. (2001), Riedesel et al. (1987), and Latzka et al. (1998), have shown that athletes who drink adequate fluids 1 hour before exercise have lower core temperatures and heart rates during exercise compared to a control group who did not drink fluids. Likewise, in a study by Armstrong et al. (1985), subjects performed runs of 5,000m and 10,000m in either a normally hydrated or dehydrated state (by 2% of their body mass). The dehydrated group had running velocities that decreased by 6% and 7% in both events! Armstrong et al. (1985) also reported that muscle strength and endurance capacity was adversely affected in a state of dehydration. It should be noted that the difference between a gold medal and fourth place in the Olympic Games is less than 1%!

Hyponatremia

Hyponatremia occurs when the body takes in more water than it loses, cells become hypotonic and swell with water to dangerous levels. The result is too much water and not enough sodium. Thus, hyponatremia generally results in low sodium levels in the blood. Usually, drinking large amounts of water does not cause over hydration if the pituitary gland, kidneys, liver, and heart are functioning normally. To exceed the body's ability to excrete water, an adult with normal kidney function would have to drink more than 2 gallons of water a day on a regular basis (Tortora and Grabowski 2000).

Table 1. Marathon Hyponatremia facts

2002 Boston Marathon facts:

- Sample of 481 participants
- 13% of participants experienced hyponatremia
- Risk factors:
    - Female gender
    - Slower finishing times
    - Excess fluid consumption

Hyponatremia is often associated with long endurance events such as marathon running. Medical teams at the 2002 Boston Marathon reported a 13% incidence of hyponatremia at the event medical tent (Table 1). The medical teams reported higher incidence in female runners, runners with slower finishing times and runners who consumed excess fluid.

Brain cells are particularly susceptible to hyponatremia (as well as dehydration). When hyponatremia occurs slowly, brain cells have time to adapt, so few symptoms occur. When hyponatremia occurs quickly, confusion, seizures, coma may develop, or may lead to death if left untreated.

The symptoms of hyponatremia must be very carefully diagnosed, due to their similarity to symptoms of dehydration.

- Headache
- Nausea
- Confusion
- Convulsions
- Coma

Assessment of Hydration in Athletes

The assessment of hydration in athletes is a debated issue in the scientific community. There is presently no agreement for using any one approach over another in the athletic setting. There are however, several simple tests that a coach or athlete can use to evaluate hydration that are recommended by the U.S. Olympic Committee.

Urine concentration is best assessed by checking the athlete's *urine specific gravity* (USG) from a sample collected during the first void of the morning (Shirreffs and Maughan 1998). Evaluation of USG *combined with body mass measurements* is a method for quantifying the hydration level of an athlete, and is the preferred method used at the U.S. Olympic Training Centers.

USG is easily measured using a handheld refractometer (see right) and all that is required is a few drops of urine from the athlete in the morning. The technician of the refractometer looks into the tube and can visually see the concentration of water versus other matter in the urine. Below is a chart developed by Kavouras (2002), that shows USG values in correlation to hydration status and body mass gain/loss (Table 2).

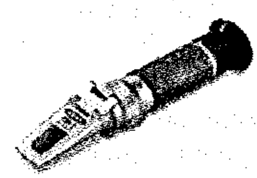
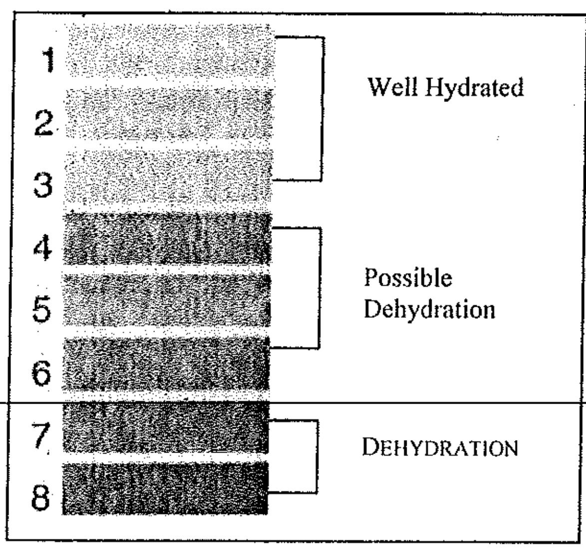


Table 2. USG Comparison Chart

Hydration Status	% Body Weight Change*	USG
Well hydrated	+1 to -1	<1.010
Minimal dehydration	-1 to -3	1.010 – 1.020
Significant dehydration	-4 to -5	1.020 – 1.030
Serious dehydration	< -5	>1.030

*Body weight change = [(baseline body weight – assessment body weight) / baseline weight] x 100

Figure 5. Urine Color Chart



A refractometer may not always be available to the coach and athlete. Armstrong et al. (1998) developed a quick and effective way to estimate hydration status in the field, when no laboratory equipment is available by simply looking at urine color (Figure 5).

The Urine Color Chart has several levels of urine color with 1, 2 and 3 being well hydrated; 4, 5 and 6 being possibly dehydrated; 7 and 8 being dehydrated.

However, it should be noted that consuming large amounts of B vitamins can cause darkly colored urine even if the athlete is well hydrated.

EFFECTS OF HEAT, HUMIDITY AND COLD

When competing in adverse climates, remember that although you can't change the weather, you can beat it! Heat, humidity and cold environments pose an additional challenge to endurance athletes. As environmental temperatures get too high or too low, race times tend to decrease.

We typically hear mention on radio/TV of "the" temperature, which is in fact shade temperature unaffected by sun or breeze or surrounding warm structures. The impact of climate on performance has many more influencing factors than just shade temperature:

1) High humidity adds discomfort to a warm temperature
2) A breeze makes us feel cooler (evaporation/convection)
3) We feel warmer when bathed in sunshine - we are taking on radiant energy
4) The summed effect of all these elements is called climatic heat stress

Heat and Humidity

The human body is warm. The same body under stress is even warmer. That is why heat can pose such a threat to endurance athletes.

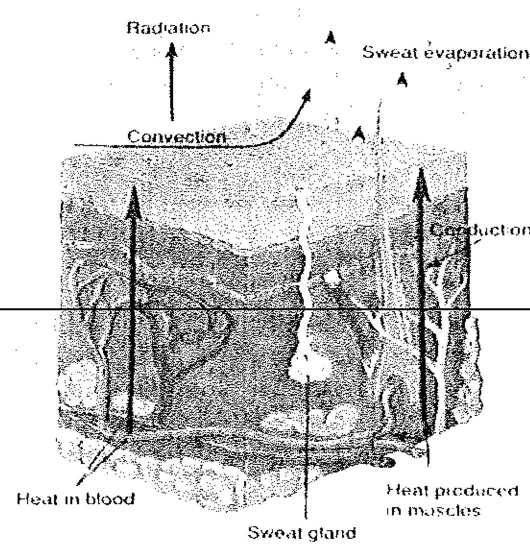
The human body at rest is an average of 98.6° F. Enzymes function optimally at 102.2° F and at 105° F performances decline as enzymes begin to break down due to increased heat. As you can see, the temperature margin that is acceptable for homeostasis is very narrow; therefore the human body must strictly regulate core temperature.

During exercise, there is a significant increase in energy expenditure. It is estimated that 60% to 70% of the energy generated during exercise is released as heat; 20% to 30% is used for movement. This is why we feel warm when running even in cool weather. This extra heat cannot accumulate and must be dissipated, somehow. If heat is not dissipated, then heat illness may occur.

There are basically four mechanisms for transferring heat to and from the body. These mechanisms shown in Figure 6 include:

- Convection – direct contact with warm or cold object
- Conduction – direct contact with gas or liquid
- Radiation – gain or loss of infra-red energy/heat
- Evaporation – heat dissipation from sweat changing physical states (liquid to gas)

Figure 6. Mechanisms of Heat Dissipation



Evaporation occurs because sweat warms and is turned from a liquid to a gas and the result is heat dissipation (Figure 6). Evaporation is responsible for over 80% of total heat dissipation; therefore it is our most important heat loss mechanism. However, as temperature rises, the volume of sweat produced rises as well. For this reason, sweating cools the body more rapidly, but puts the athlete at a greater risk of dehydration. The athlete must stay well hydrated to maintain the evaporative potential.

Heat Illnesses

If the body cannot dissipate heat efficiently, then it will accumulate and may cause damage beyond dehydration. Table 3 lists several heat illnesses that may result from training or competing in conditions of poor hydration or extreme heat and humidity.

Table 3. Heat Illnesses

	Heatstroke
Cause:	Overwhelmed or failed thermoregulatory system.
Core temp:	$\geq$ 104°F
Symptoms:	Headache Lack of mental clarity Bizarre behavior Lack of sweat
Treatment:	Reduce core temp immediately via ice water immersion. i.v. fluid replacement.
Prevention:	Adequate heat + humidity acclimatization. Proper clothing / uniform.
	Heat Exhaustion
Cause:	H_2O + Electrolyte imbalance via dehydration.
Core temp:	102° - 104°F
Symptoms:	Headache Fatigue / Weakness "Heat sensations" in head, neck, arms Nausea or vomiting
Treatment:	Restore H_2O + Electrolyte imbalance via CHO-E drink.
Prevention:	Adequate heat + humidity acclimatization. Adequate H_2O + Electrolyte replacement.
	Heat Syncope
Cause:	Temporary lack of blood to the brain due to pooling of blood in legs.
Core temp:	<102°F
Symptoms:	Fainting (syncope)
Treatment:	Elevation of legs and pelvis
Prevention:	Adequate heat + humidity acclimatization. Avoid sudden stop after high-intensity exercise – "keep moving" to prevent pooling of blood in legs.
	Heat Cramps
Cause:	Electrolyte (Na+) imbalance via dehydration and inadequate dietary Na+.
Core temp:	<102°F
Symptoms:	Severe muscle cramps in abdomen and large muscle groups.
Treatment:	Restore Na+ imbalance via CHO-E drink and increased dietary Na+.
Prevention:	Adequate heat + humidity acclimatization. Adequate Na+ intake in diet and during exercise.
Key:	CHO-E = Carbohydrate-electrolyte Na+ = Sodium

Risk Factors for Heat Illnesses

There are many risk factors associated with heat illnesses. Here are a few:

- Elite athlete (high sweat loss, high electrolyte loss, more intense work loads, etc.)
- Lack of acclimatization
- Dehydration
- Glycogen depletion
- Non-porous clothing
- "Two-per-day" practice format
- Concurrent illness (febrile)
- Sleep loss
- History of heat illness
- Relatively large muscle mass
- Females during luteal phase of the menstrual cycle
    - progesterone > estrogen
    - core temp increases by ~1°F
    - core temp peaks between day 19 and 24 of a normal 28-day menstrual cycle
- Drugs/ Medications
    - sympathomimetics (e.g., ephedra)
    - anticholinergics (e.g., antihistamines)
    - diuretics
    - cyclic antidepressants
    - monoamine oxidase inhibitors
    - alcohol

Acclimatization to Heat and Humidity

Pre-event acclimatization can help an athlete to optimize performance in a hot and humid environment. Becoming acclimatized to the competition environment has many physiological benefits that can improve performance. Effective acclimatization requires at least 14 days for an athlete to become 95% acclimatized for warm or hot environments (Table 4).

Table 4. "Plateau days" of Physiological Adaptations (point at which 95% of the adaptation occurs) during heat acclimatization.

Adaptation	Days of heat acclimatization													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Heart rate decrease			—	—	—									
Plasma volume expansion			—	—	—									
Rectal temperature decrease					—	—	—	—						
Perceived exertion decrease			—	—	—									
Sweat Na^+ and Cl^- concentration decrease*					—	—	—	—	—					
Sweat rate increase								—	—	—	—	—	—	—
Renal Na^+ and Cl^- concentration decrease			—	—	—	—	—	—						

* While consuming a diet low in NaCl.

Reprinted from Armstrong and Dziados 1986.

The best way to properly acclimatize is to live and train in an hot and humid environment. For example, several US Olympic Team athletes lived in and around Athens, Greece for several weeks prior to the Athens 2004 Summer Olympics. This strategy not only allowed those athletes to effectively acclimatize to the heat and humidity of summertime Athens, but it also allowed them to adjust to the new time zone. Some US Olympic Team athletes lived and trained in hot and humid locations throughout the United States prior to going to Athens. This allowed them to effectively acclimatize to the heat and humidity of summertime Athens, but gave them less time to adjust to the new time zone.

Table 5 shows a 14-day heat and humidity acclimatization protocol including a 4-day pre-competition taper period. This protocol assumes two training sessions a day for the first 10 days, followed by one training session during the 4-day taper. The athlete should begin with low intensity (**LI**) workouts during the coolest parts of the day (morning and evening) for the first few days, after which time the athlete should feel comfortable adding a high intensity (**HI**) workout in the early morning. Notice how the high-intensity training session is gradually moved toward the hotter, middle part of the day from day 4 to day 10. This gradual exposure to greater heat and humidity will allow for optimal acclimatization while simultaneously allowing the athlete to train effectively.

Table 5. Protocol for heat and humidity acclimatization including a pre-competitive taper.

Day 1	Morning	**LI**	Noon	**LI**	Evening
Day 4	Morning	**HI**	Noon	**LI**	Evening
Day 7	Morning	**HI**	Noon	**LI**	Evening
Day 10	Morning	**HI**	Noon	**LI**	Evening
Days 11-14 taper	Morning	**LI**	Noon		Evening

Key: **LI** = low intensity training session
HI = high intensity training session

If an athlete is unable to live and train in a hot and humid environment, there are some other options for effective acclimatization. For example, US Olympic Team marathon runners lived and trained at altitude prior to the Athens Olympics. As such, they were not exposed to a hot and humid environment. However, they effectively "simulated" the summertime heat and humidity of Athens by progressively adding layers of clothing (sweats, ski hats, etc.) during training sessions, which allowed them to acclimatize to heat and humidity while simultaneously maintaining their altitude training. This strategy proved very effective for the US Olympic Team marathoners as they had their best performance ever in the 2004 Athens Games, winning a bronze medal in the women's race and a silver medal in the men's race. Modifications of this strategy include training in an environmental chamber or sauna, both of which are less practical for most athletes.

Some of the physiological benefits to heat and humidity acclimatization are:

1. Increase in Plasma Volume (PV)
   - An increase in plasma volume is brought on by hormonal changes that lead to greater retention of water and sodium in the blood. This increase in PV is also an increase in the total blood volume (TBV). Having more blood allows the athlete to cool more effectively by enhancing the body's capacity to cool itself via evaporation, convection and radiation. This is analogous to your car having more coolant in its radiator.

2. More effective distribution of Cardiac Output (Q)
   - Enhances the circulation of blood to skeletal muscle, in order to meet the demands of exercise and the shunting of blood to skin in order to dissipate heat. It also gives the athlete a greater stability of blood pressure during exercise.

3. Earlier threshold for the onset of sweating
   - Dissipation of heat via evaporation begins *earlier* in exercise. This is analogous to your home's air conditioning turning on at a *lower* temperature on the thermostat.

4. More effective distribution of sweat over skin surface
   - Greater dissipation of heat via evaporation.

5. Sweat output increases
   - Greater dissipation of heat via evaporation.

6. A decrease of salt (Na+Cl-) concentration in sweat
   - More "dilute" sweat preserves electrolyte balance in extracellular fluid.

It is always important for the coach and athlete to assess hydration levels when taking on an acclimatization strategy. The decrease in total body weight should not be greater than 1%, urine color should remain at a 1, 2 or 3 on the Urine Color Chart and USG should not be greater than 1.020. Core temperature should also be monitored and not exceed 102°F.

Training in a dehydrated state will **not** create physiological adaptations to competing in a dehydrated state!

Cold

Cold environments can pose a threat to the hydration levels of endurance athletes. Cold air can increase water loss and augment dehydration.

First, many athletes drink too little fluids in cold weather because the thirst center's signal can be curbed. Also, common sense shows that athletes often resort to hot cups of coffee and tea during winter months which are diuretics and may lead to dehydration.

Secondly, urine output is increased with cold environmental exposure. This is called Cold-Induced Diuresis (CID) (Freund and Sawka 1996).

Cold air also has less water vapor, in other words a lower relative humidity. As air enters the respiratory tract during inhalation, the air is warmed and humidified. If relative humidity is high, less water from the respiratory tract and skin can saturate the entering air. If relative humidity is low, as with cold air, then more insensible water loss (water loss from the skin and respiratory tract) results.

Sports Drinks

The sport drink market has exploded over the past several years. New products seem to be emerging almost as fast as records fall. Gatorade®, PowerAde®, Cytomax®, Endurox®, etc. the list goes on and on. So the question is: are all the sports drinks just hype? The answer is no.

When performance is a key consideration in a workout or competition, a sport drink has documented advantages over plain water.

Plain water will quench thirst but it is ineffective at rehydrating because water absorption causes plasma osmolarity to decrease while increasing urine output. Therefore sodium needs to be provided, either in fluid or foods, and the osmotic drive to drink is maintained and urine production is suppressed.

First of all, sports drinks are sweet in taste. It is no surprise that most humans prefer a sweetened beverage over plain water. This encourages more voluntary fluid intake.

Secondly, the sweet taste of sports drinks comes from the carbohydrates in the drink. Carbohydrates not only improve the taste of the beverage, but they provide a fuel source for active muscles, and stimulate fluid absorption from the intestine. Although it is clear that carbohydrate can improve performance, more carbohydrate in a beverage is not necessarily better. Some research has shown that a beverage containing more than 14g of carbohydrate per 8-ounce serving will decrease the rate of gastric emptying (Horswill 1988) and fluid absorption (Ryan et al. 1998).

Thirdly, precious electrolytes (e.g. sodium, potassium, chloride) are lost in sweat. Sports drinks that contain small amounts of electrolytes can replace those lost during exercise.

Other Considerations

Altitude

In the past few decades endurance athletes have relocated to moderate elevations in order to acquire the benefits of training with less oxygen content in the bloodstream. Although the benefits of altitude training are still debated among physiologists, coaches and athletes, there are still important hydration issues that need to be addressed by athletes living and training at moderate altitude.

Proper hydration is of special concern for athletes training at altitude. Water loss is increased greatly at altitude due to increased respiratory water loss and increased urinary water loss to due to the down-regulation of water retention hormonal mechanisms. According to Butterfield et al. (1992), respiratory water loss at moderate altitude (8,200 to 14,110 feet) may be as high as 1,900 ml per day in men. Likewise, Mawson et al. (2000) have reported that respiratory water loss may be as high as 850 ml per day in women. Urinary water loss, as reported by Butterfield (1996), may average 500 ml per day.

As you can see it is just as important to stay well hydrated at altitude as it is in hot/humid weather. Athletes need to maintain proper hydration by making sure they follow the proper techniques of hydration during performance and also the non-workout part of the day.

Air Travel

Endurance sporting events are held world-wide. Traveling by air is a necessity of the elite endurance athlete, in order to find elite level competitions. May sub-elite athletes also travel to competitions throughout the United States and sometimes beyond.

Air travel affects hydration levels in much the same way high altitude does. There is an increase in respiratory and urinary water loss due to the high altitude of the cabin. Passenger cabins usually pressurize at about 6,000 ft, and can pressurize as high as 9,000 ft.

Air on board a plane is also very dry. The relative humidity of a plane's cabin ranges from 1% to 27%, with an average of 6%. This low relative humidity enables more water loss from the respiratory tract. Freund and Sawka (1996) reported an insensible water loss of 700 to 1000 ml/d at sea level in a temperate climate. Water loss in a lower relative humidity may be up to 750 to 1000 ml higher.

Airlines serve beverages during the flight that can be diuretics (coffee, caffeinated soda, tea, alcohol). These beverages should be avoided by the athlete during the flight.

Hydration levels during flight may also be adversely affected because many passengers avoid drinking enough fluids due to the inconvenience of restroom visits.

In brief, air travel can become an obstacle in an endurance athlete's proper hydration. The best way to combat this is to plan ahead accordingly by bringing your own beverages on board a plane and continuing proper hydration practices.

RECOMMENDATIONS FOR PROPER HYDRATION

Many professional organizations such as the American College of Sports Medicine, USA Track and Field, the National Athletic Trainers Association and the Association of International Marathons have published a position stand on proper hydration.

Year	*Position Stand*	*Pre-Exercise* Time	*Pre-Exercise* Quantity	*During Exercise*	*Post-Exercise* Time	*Post-Exercise* Quantity	*Electrolyte Replacement*
2003	**USA Track & Field**	2-3 hours before exercise	Drink 17-20 oz of fluids	No more than 8-10 oz every 15-20 minutes	4-6 hours after exercise	Drink 25% more than sweat losses	Add modest amounts of sodium (0.5-0.7 g/L). This can offset sodium losses and minimize health risks
		0-10 minutes before exercise	Drink 10-12 oz of fluids				
2002	**Association of International Marathons**	No strategy		Drink fluids as needed between 13.5-27 oz depending on pace and environment	No strategy		No strategy
2000	**National Athletic Trainers Association (NATA)**	2-3 hours before exercise	Drink 17-20 oz of fluids	Fluid replacement should equal fluid loss, keeping body weight loss <2%	4-6 hours after exercise	Drink 25%-50% more than weight loss	Add modest amounts of sodium (0.3-0.7 g/L). This can offset sodium losses and minimize health risks
		10-20 minutes before exercise	Drink 7-10 oz of fluids				
1996	**American College of Sports Medicine (ACSM)**	2 hours before exercise	Drink 17 oz	Start drinking early and at regular intervals at a rate that will replace fluid losses	No strategy		For exercise lasting more than 1 hour, add 0.5-0.7 g/L of sodium

SUMMARY

In summary, the body is composed mostly of water and the kidneys act as a filtering unit for the plasma (water) portion of the blood. The kidneys are equipped to conserve or excrete urine based on the hydration state of the person. If dehydration or over hydration occurs, blood osmolarity changes and the kidneys act to maintain homeostasis. Dehydration and over hydration have shown to significantly decrease athletic performance, especially in the (high-risk) endurance athletes. There are several markers and consequences, beyond decrements in athletic performance, which results from improper hydration.

There are several ways to assess hydration status by the coach or athlete however checking urine specific gravity and body mass is the easiest and possibly least expensive. If a refractometer and/or scale is not present, urine color can be indicative of hydration status and is a useful "field guide".

Heat and humidity can exacerbate dehydration or fool the athlete into drinking too much. The best way to combat environmental changes is to acclimate to the competition environment.

A 2-week acclimatization plan will create 95% of the physiological changes needed for the new environment, in the athlete.

Sports drinks are proven sources of rehydration because they increase voluntary intake of fluids and many of them contain small amounts of electrolytes that enhance absorption of the fluid as well as replace valuable electrolytes that were lost during exercise.

Some other considerations such as living and/or training at altitude, air travel and chronic dehydration create special circumstances for the athlete in order to maintain hydration. Altitude increases urinary output and water loss through respiration. Lastly, chronic dehydration from 2-per-day practices or travel schedules must be combated with proper hydration techniques.

There are several scientific and athletic nation-wide organizations that have position stands on proper hydration techniques for athletes.

The purpose of this paper is to educate those who read it on the risks and benefits of hydration in endurance athletes.

Recommended Reading

Position Stands

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