Hydration

7.1 - Why are fluids important for all athletes during exercise?

Proper hydration is important for all athletes in order to:

(1) Replace water lost as a result of sweating;

(2) Avoid marked decreases in performance that result from dehydration;

(3) Help maintain body temperature within acceptable limits during exercise.

During prolonged exercise, carbohydrate drinks are also recommended, as they can help the athlete perform at his or her best by providing simultaneously both fluids and energy.

7.2 - Fluid Losses/Replacement During Exercise

7.2.1 - Sweat Rate

During exercise, fluid losses are due to sweating (mostly) and breathing (to a lesser extent). Sweat rate is influenced by factors such as exercise intensity and environmental conditions: the higher the intensity, and the hotter and more humid the environmental conditions, the greater the sweat rate. For instance, during moderately intense exercise in comfortable conditions, sweat rate can vary between 1.2 and 1.5 liter per hour (between 5 and 6.5 cups). During intense exercise, these values can exceed 2.0 liters per hour (8.5 cups), while under extreme conditions of heat and humidity sweat rate can be as high as 3.0 liters per hour (12.5 cups) in elite athletes.

If fluid losses are not replaced, performance will decrease. Furthermore, when large amounts of water are lost as a result of profuse sweating, the athlete may suffer from life-threatening heat-related injuries.

7.2.2 - Rate of Fluid Absorption

During exercise, the body usually loses water at a faster rate than it can absorb it. The rate of fluid absorption varies among individuals, but usually ranges between 10 and 15 ml per kg body weight per hour. For most athletes, this means that roughly 700 to 1000 ml (3 to 4.25 cups) of fluid can be absorbed over a period of 60 minutes. However, because sweat rate often exceeds 1.5 liters (6.5 cups) per hour during heavy training or competition, most exercise conditions tend to be associated with a water deficit.

7.3 - Consequences of Heavy Sweating

7.3.1 - Physiological Effects

Heavy sweating leads to a reduction in plasma volume, an increase in heart rate during submaximal exercise, a decreased capacity to supply working muscle with nutrients and oxygen, and a reduced capacity for the body to get rid of the heat produced as a result of muscle contractions. The combined effect of these factors is an increase in core temperature and a decreased work capacity. Because sweat contains proportionally more water and fewer electrolytes than plasma, significant fluid losses also increase the concentration of electrolytes in the blood.

As will be outlined in the following sub-sections, the consequences of dehydration, both in terms of its effects on performance and potential health risks, are related to the decrease in the subject's body weight.

7.3.2 - Effects of Dehydration on Performance

It is generally agreed in the scientific literature that dehydration negatively affects performance and is associated with premature fatigue. This is particularly the case for prolonged aerobic exercises such as distance running or cycling, but athletes competing in team sports or events of short duration can also be affected by dehydration. For instance, aerobic performance is decreased at dehydration levels as low as 1 or 2% of the subject's body weight. There is less evidence that dehydration has negative effects during anaerobic or strength-power exercises, although some data also report a decrease in performance.

The following table presents a summary of the effects of dehydration on performance and selected physiological variables.

Effects of dehydration on performance and selected physiological variables.
-3- or -4% BW: Dehydration level corresponding to approximately 3 or 4 percent of the subject's body weight.

Variable	Effect of dehydration
Maximal speed	Unaffected or decreased
Reaction time	Unaffected
Aerobic endurance, sub-maximal intensity	Decreased
Aerobic endurance, near maximal intensity	Decreased
Endurance at maximum oxygen consumption	Decreased
Anaerobic capacity	Decreased
Anaerobic power	Decreased
Energy cost at sub-maximal intensity	Unchanged
Sweat rate	Decreased at –3 or –4% BW
Rate of fluid absorption	Decreased at –3 or –4% BW
Skin blood flow	Decreased at –3 or –4% BW
Capacity to dissipate heat	Decreased at –3 or –4% BW
Core temperature at sub-maximal intensity	Increased
Blood lactate concentration	Increased
Maximum heart rate	Unchanged
Maximum oxygen consumption	Decreased

7.3.3 - Low Dehydration Level

A dehydration level of less than 2% of the subject's body weight (approximately 1.5 liters (6.5 cups) for a 70 kg (154 lb.) individual) has no grave consequences on the individual's health. However, as indicated previously, dehydration levels as low as 1% of the athlete's body weight can negatively affect performance, particularly in the case of aerobic exercises.

7.3.4 - Moderate Dehydration Level

When dehydration reaches between 3-5% of the subject's body weight, the risk of heat-related injury is high. The volume of extra-cellular liquid is significantly reduced, leading to an increased concentration of electrolytes in the plasma (increased osmolarity). This is accompanied by a decreased blood volume and cardiac output. Consequently, less blood can be directed to the working muscles and to the skin. Under these conditions, sweat rate decreases progressively to avoid further fluid losses which could result in central blood pressure reaching dangerously low levels. When this occurs, the body's ability to rid itself of the heat produced by working muscles is considerably reduced; core temperature can rise rapidly, and reach 104-106 degrees Fahrenheit. This is a dangerous situation.

7.3.5 - Severe Dehydration

When dehydration exceeds 5-6 % of the subject's body weight, in particular if it reaches 7-8%, the risk of overheating is extremely high, and this represents a life-threatening situation. It is sometimes possible for an athlete to continue exercising under such conditions, but power output is considerably reduced and the subject is not really conscious of his or her actions. He or she can experience vertigo, spasms, or respiratory problems, while core temperature can reach or exceed 106 degrees Fahrenheit. When this occurs, the body's thermoregulatory centers may no longer be able to function properly, and the subject can begin shivering as though he or she were cold. Under such conditions, if the subject does not stop exercising immediately, and if emergency treatments are not initiated at once, cardiac arrest can occur.

7.4 - Differences in Sweat Rate

7.4.1 - Gender Differences

Males and females with a similar level of fitness and heat acclimation usually show no difference in their ability to exercise in the heat. However, it is well known that significant differences exist among genders in the area of sweat rate: under similar conditions of heat and humidity, males sweat more than females. On average, the core and skin temperatures at which females begin sweating is higher, and the electrolyte concentration (sodium; chlorine) in their sweat is greater. The reasons for these gender differences are not fully understood.

On average, the ratio surface area to body mass is higher in females than in males, e.g., per unit body weight females tend to have a greater skin surface exposed to the environment.

Compared to males, it is therefore generally acknowledged that females are:

(1) more dependent of circulatory adjustments to dissipate heat during exercise, and
(2) less at risk of suffering from severe dehydration during exercise, particularly under hot and humid conditions where large amounts of water can be lost.

7.4.2 - Age Differences

The sweat rate of children is considerably less than that of adults. Children also have a small surface area which limits heat exchanges with the environment. Consequently, children usually do not have a good capacity to rid themselves of metabolic heat during exercise performed in hot and humid conditions.
(Note: Recent data indicate that children drink more if the fluid is flavored. Increasing the palatability of the drink with glucose (40 to 80 grams per liter) and a pinch of salt, or making special sport drinks available to them, is a good way of ensuring children get enough fluids when exercising in hot conditions.)

7.5 - Thirst Sensation and Dehydration

Thirst sensation is regulated by the hypothalamus, a gland located in the brain, in response to an increase in the blood osmotic pressure. Although the exact mechanism responsible for thirst control is not yet fully understood, it is well established that the sensation of thirst is not a good indicator of an individual's level of dehydration. When thirst manifests itself, approximately 2% of body mass has been lost. Consequently, one cannot gauge dehydration by referring to his or her thirst sensation. During exercise, it is therefore important to drink before feeling thirsty, and even if one does not feel thirsty.

If thirst were the only point of reference used for determining fluid needs following profuse sweating, re-establishing the body's water content could take up to 24-48 hours.

7.6 - Characteristics of Exercise Drinks

7.6.1 - Temperature

Several studies have shown that a cold beverage is absorbed at a faster rate than a warm drink or a drink at body temperature. Contrary to what many people believe, a cold drink will not cause cramps during exercise. In practice, the temperature of an exercise drink should be approximately 10-12 degrees Celsius.

7.6.2 - Composition

The composition of fluids consumed during exercise often represents a source of confusion. Recent studies have shown that the rate of absorption of a glucose solution is optimal when its concentration ranges between 40 and 80 grams per liter. During prolonged exercise in the heat, it may be advisable to consume beverages whose concentrations do not exceed 40 to 60 grams per liter to maximize the rate of water absorption.

Adding small amounts of salt (0.5 gram per liter of water) is also recommended to increase the palatability of the beverage and thus encourage the intake of greater amounts of fluids.

7.7 - Amounts of Fluid to Consume During Exercise
The amount of fluid an individual should consume during exercise depends of the rate of absorption. This amount varies from one person to another, but usually ranges between 10 and 15 ml per kg (1/2 cup per 25lbs) body weight per hour. On average, an amount of 12 ml per kg body weight per hour should be close to the maximum quantity of fluid most people can absorb, although it is best to drink as much as one can tolerate without feeling any discomfort. The following table provides an outline of the amounts of fluids to consume during exercise according to body weight. Athletes should drink regularly during exercise, e.g. every 10 or 15 minutes.

Amounts of fluids to consume during exercise according to body weight

Individual Body Weight (lbs)		110	132	154	176	198
Total Volume (cups/hour)	2.5	3.0	3.5	4.0	4.5	
Frequency						
Every 15 minutes (cups)	2/3	3/4	7/8	1	1 1/8	
Every 10 minutes (cups)	2/5	1/2	1/3	2/3	3/4	

Individual Body Weight (kg)	50	60	70	80	90
Total Volume (ml/hour)	600	720	840	960	1080
Frequency					
Every 15 minutes	150	180	210	240	270
Every 10 minutes	100	120	140	160	180

7.8 - Fluid Consumption Before Exercise
It is generally recommended to drink water before an exercise. The advantage of such a practice is not to make water reserves (this is not possible, as excess fluids are eliminated through urine), but rather that is associated with:

(1) a more efficient thermolytic response (sweating begins at a lower body temperature, and is more abundant); and
(2) an enhanced rate of absorption of the fluids consumed during exercise.

In practical terms, it is suggested to drink approximately 8 to 10 ml per kg body weight of fluids two hours before an exercise (600 to 900 ml) in small amounts at a time. It is important to note that this will be associated with the production of some urine, which will have to be eliminated before the effort begins.

7.9 - Post-Exercise Rehydration
After an exercise where sweating has been profuse, it is extremely important to rehydrate the body. As indicated before, one should not gauge his or her fluid needs by the sensation of thirst. Consequently, a forced hydration is often necessary. It is possible to estimate how much fluid an individual has lost during exercise by weighing before and after the activity. The difference in kg should represent the amount of fluid lost, in liters, since one liter weights one kg. For each kg body weight lost, at least 1.25 liter of fluid should be consumed. It is important to drink more than one liter per kg body weight lost to account for urinary losses. Dehydration level can also be monitored by assessing the color and smell of urine. Dark, scanty urine signals a need for more fluid and, under these conditions, voluntary hyperhydration is necessary.

7.10 - Minerals and Electrolytes

7.10.1 - During Exercise for most Sports
Since sweat consists mainly of water, not electrolytes (such as sodium, potassium and chlorine), adding more than 0.5 gram of salt per liter of beverage, or consuming salt tablets during exercise in an attempt to replace electrolytes, is contraindicated. In fact, consuming large amounts of salt during exercise slows the absorption

of water, thus further accentuating plasma losses. It can also lead to an overconcentration of electrolytes in the blood, and potentially dangerous repercussions on the heart (cardiac arrest).

7.10.2 - Extremely Prolonged Exercises

In the case of extremely prolonged exercises such as ultra-marathons or the Hawaii Ironman Triathlon where large amounts of fluids are consumed, hyponatraemia (e.g. a reduced sodium concentration in the blood) is possible, though rare. This condition can lead to dizziness or confusion. It is currently acknowledged that this can be prevented by adding a small amount of sodium to the exercise drink (0.5 gram per liter of water).

7.10.3 - After Exercise

After exercise, electrolytes lost as a result of sweating can be replaced by adding small amounts of salt to the post-exercise meal, or by consuming beverages such as tomato or vegetable juices. In general, the North American diet contains enough sodium to replace losses due to exercise.

Replacing electrolytes after an exercise is extremely important, otherwise rehydration will be incomplete. The following sections present lists of foods that are rich in sodium and potassium.

7.11 - Sodium-Rich Foods

The foods in this list contain approximately 500 mg of sodium.

Foods	Portions
Salted peanuts	4 oz (120 g)
Bacon	6 slices
*Commercial meat broth	1/2 cube
Salted chips	1 small bag (50 g)
Ham	2 oz (60 g)
Olives	3 average-sized
All-dressed pizza	1 small slice
*Canned stew	1/2 cup (125 ml)
Sardines	2 oz (60 g)
*Soya sauce	1 table spoon (5 ml)
*BBQ sauce	3 table spoons (50 ml)
Pork sausage	2 pieces
Smoked pork	1 piece
Bologna sausage	2 slices, average thickness
*Canned salmon	3 oz (90 g)
*Canned soup	1/2 cup (125 ml)
*Spaghetti with canned tomato sauce	1/2 cup (125 ml)
*Canned tuna	3 oz (90 g)
Prepared meat, salami, pepperoni	1 oz (30 g)
*Salt	1 packet (1 g or 1 ml)

* : lower fat choices.

7.12 - Potassium-Rich Foods

Each of the following portions contain approximately 300 mg of potassium, which is the amount lost in 1.5 liter (1.5 kg or 3 lbs) of sweat.

Milk and Milk Products

- 1 cup (8 oz) whole milk, 2% skim
- 2 small containers of plain or fruit yogurt (2 x 4 oz)
- 1 bottle (200 ml) yogurt drink
- 1 bottle (200 ml) chocolate milk
- 1 cup (250 ml) of iced milk

Note: Cheese and ice cream are not potassium-rich foods.

Fruit

Juice	Fresh or	Canned Dried
¾ cup (200 ml) orange juice	1 orange	3 dried apricots
¾ cup (200 ml) grapefruit juice	3 fresh apricots	6 dried dates
¼ cup (125 ml) prune juice	4 slices canned pineapple	¼ cup (65 ml) raisins
1 cup (250 ml) grape juice	2 figs	1 cup (250 ml) raisins
1-1/2 (325 ml) orange juice	¼ avocado	
	6 prunes	
	1 small banana	
	½ cantaloupe	
	1-1/2 cup (325 ml) strawberries or raspberries	
	2 big slices of watermelon	

Note: Fruit drinks (which contain sugar, water, flavorings and artificial colorings), lemonade, and cranberry juice are not good sources of potassium. Apples and blueberries contain the least potassium of all types of fruit.

Vegetables

- 1 small potato
- 1 average portion of broccoli
- 2 carrots
- 1 tomato
- 6 stalks of asparagus
- 3 stalks of celery
- 1 large portion of cauliflower or Brussel sprouts
- 3/4 cup (200 ml) tomato or vegetable juice

Note: All vegetables are good sources of potassium.

Nutrition While Traveling

8.1 - Minimizing the effects of long plane travels

- Prior to the flight, consume a diet high in complex carbohydrate to maximize glycogen storage. Fluid stored with the glycogen will help to prevent dehydration.
- During the flight, emphasize high carbohydrate, low fat foods. Vegetarian or low fat meals must be ordered in advance.
- Drink lots of cool fluids (bottled/mineral water, juices, clear carbonated soft drinks.) Start at the airport - drink 2 cups (500 ml) of fluid in the hour before departure.
- During the flight - aim for at least 1 cup (250 ml) per hour.
- Avoid excess intake of caffeine (coffee, tea; and caffeinated soft drinks -- colas), which can promote dehydration.
- Don't drink alcohol -- it may also dehydrate.
- Carry a personal "Snac-Pac" (full water bottle, cartons of fruit juice, fresh fruit, high carbohydrate snacks -- raisins, crackers, dry cereals, bagels, fig newtons, plain cookies, etc.)
- Set your watch to the destination time prior to take off.
- Stretch, exercise, or move around the aircraft as much as possible to limit stiffness and reduce the cramped feeling.
- Try to rest or sleep sometime during the flight.
- At the destination, get out into the sunshine as much as you can. Do not stay in the artificial light indoors.
- Be active and socialize at your destination. Try to "live by the clock" upon arrival, i.e., eat meals at the mealtime of your destination. Allow yourself only a short nap if you arrive in the morning.

8.2 - Guidelines for Travel in Foreign Countries

8.2.1 - General Recommendations

- Eat only in recognized restaurants.
- Choose fruit that can be peeled; the skin can contain bacteria and infectious agents.
- Avoid raw vegetables unless peeled.
- Avoid food served by street vendors.
- Bread is the best way to "put out the fire" in your mouth caused by spicy dish.
- AVOID all raw fish, raw or partially cooked meat or poultry.
- If you choose to eat at fast food restaurants, be aware that many food choices in these restaurants are high in fat.

8.2.2 - Water Consumption

- It is important to be careful when drinking water out of continental North America. Although tap water may be labeled as "safe" to drink, variations in the bacteria content may cause a gastro-intestinal upset.
- Adding ice to drinks is the same as adding tap water. Be careful, and avoid surprises!
- Use water bottle to brush teeth.

8.2.3 – Diarrhea

Diarrhea is a common problem during travels in South America, Mexico, Africa, Middle-East and Asia (and, often, other places, too!). It is often related to food contamination. In addition to the obvious discomfort that accompanies it, diarrhea can also lead to a moderate dehydration. Under these conditions, the following steps are recommended:

(1) Caffeine and alcohol should be avoided due to their dehydrating effect;
(2) Fruit juices, tonic water or decaffeinated soft drinks should be consumed;
(3) Salty foods should be consumed.

When suffering from diarrhea, products such as Pepto Bismol or Imodium can be useful to accelerate recovery. There is currently no medical evidence supporting the use of medication to prevent diarrhea. Careful selection of food is therefore the best way to avoid diarrhea during travel. Coaches and athletes should pay attention to the foods and the type of water that are consumed. In a foreign country, the following rule of thumb should be kept in mind at all times with regard to foods: "If you can't boil it, cook it or peel it, don't eat it!"