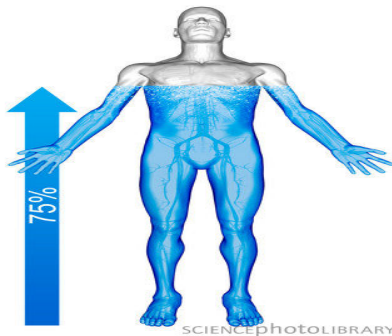


Hydration: More Than Just Water

By Jan Clementson

The Elixir of Life

Without water we will die! It is vital for all forms of life,¹ covers 71% of the Earth's surface,² and the world economy is dependent upon it.³ So, it's no surprise that civilisation has historically flourished around rivers and major waterways. Its importance to sustaining life is reflected in the amount found in the human body: approximately 60%⁴ - though it can range from 55% to 75% depending upon body size⁵ and fat tissue content. The more muscular the body, the less will be the water content.



Within the body, water performs multiple functions. It is critical to all metabolic processes; carries nutrients and wastes around the body; acts as a solvent for the dissolution of molecules; lubricates joints, the spine and the brain; and regulates temperature through sweating. Regular water consumption is necessary to replace the water lost through urine, faeces, sweating and the breath. And with physical exertion and heat exposure, the water loss will increase.

Water Requirements

*The average sedentary adult requires per day.*⁶

Males

• 2,900 ml (2.9 L)

Females

• 2,200 ml (2.2 L)

This would generally come from solid foods, which contribute approximately 1L, with the remainder coming from decaffeinated and non-alcoholic drinks.⁷ Athletes, though, will require more because their water loss is much greater. Water lost through sweat can vary considerably in individuals and will rise in a hot environment and whilst exercising in the heat.

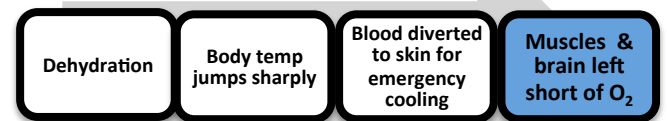
Sweat lost by runners:

Sweat loss

• 1.0–2.5 L/hr fluid

Dehydration

Dehydration is known to directly inhibit exercise performance by reducing blood volume; increasing heart rate and core temperature; reducing cognitive function; and shifting energy metabolism to glycogen reserves.⁸ Dehydration of only 1% body mass has a measurable effect on the thermoregulatory response to exercise; a 2-3% reduction will impair exercise performance; whilst a 6-7% reduction can lead to a life-threatening situation.⁹



Dehydration Performance Effects

Research has shown that at only 2-3% dehydration, athletic performance fell by 3% in the 1,500m and 7% in the 10,000m.¹⁰ To put this into perspective, if the winners (both male and female) of the 1,500m and 10,000m at the 2012 Olympics were dehydrated by 3% and 7% respectively.....then each winner would have finished LAST in their races. There would have been no 'Mobot' celebrations on 'Super Saturday' and 'Super Saturday' would have seemed.....well a lot less super!



Water Balance

All fluids in the body contain water and these fluids are found inside and outside of the cells. Within these fluids are charged particles (ions) dissolved in the water. These ions are called electrolytes and, in conjunction with certain hormones, regulate the water balance of the body to ensure optimal cell function.

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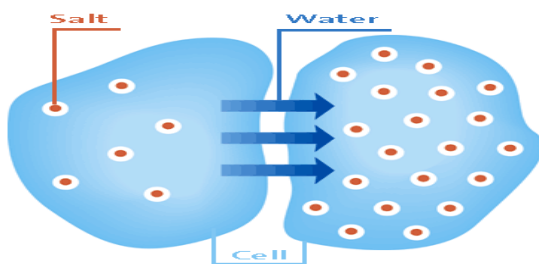
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Electrolytes

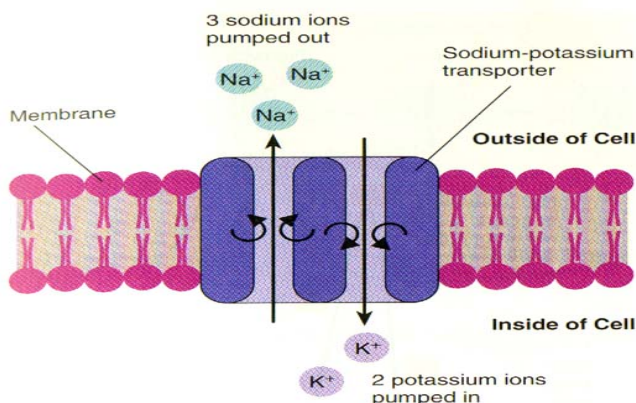
The primary electrolytes are sodium (Na^+), potassium (K^+), calcium (Ca^{2+}), magnesium (Mg^{2+}), chloride (Cl^-), phosphate (PO_4^{2-}) and bicarbonate (HCO_3^-). These ions carry electrical charges and conduct electrical activity within the body. Sodium is the main electrolyte found outside the cells, whilst potassium is the main electrolyte found inside of the cells.

Electrolyte Functions

Cells need to be bathed in fluids, both inside and out. Electrolytes maintain fluid balance by regulating the fluid passage across the semi-permeable cell membrane via osmosis – a process that causes water to move into a region with a higher solute concentration. Hence, ***water follows the charged particles.***



The electrolytes themselves enter or leave the cells via an active transport system. A pump mechanism moves sodium and potassium ions in opposite directions across the cell membrane – pumping three sodium ions out of the cell for every two potassium ions.

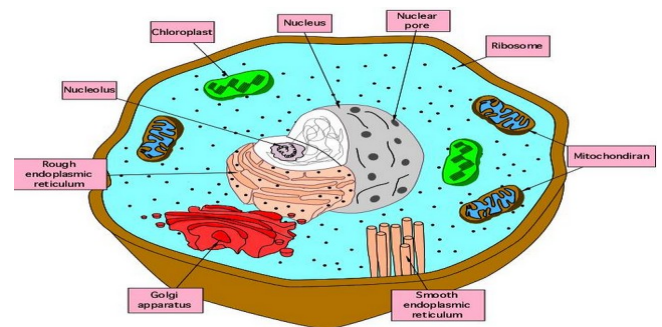


Export of sodium from the cell provides the driving force for several secondary active transport carriers, including those that transport nutrients into the cell and wastes out of it. The difference of electrical balance inside and outside of the cell also allows for the transmission of nerve impulses; contraction or

relaxation of muscles; blood pressure control; proper gland functioning; and pH balance.

Cell Functions

The cell is the basic structural, functional and biological unit of all living organisms. Within the cells are a number of structures that enable vital functions of the body to occur. These structures house hereditary information (DNA), which helps regulate cell functions,¹¹ and energy production sites (mitochondria), where all energy is produced.



Approximately two-thirds of the body's fluid is inside of the cells, whilst a third is outside of the cells. Both the amount of water and the concentration of electrolytes are important to bodily functions. When the body is in "fluid balance", it means that the various body compartments (cells, tissues, organs) contain the required amount of fluids to carry out normal function and that the volume of fluid in each compartment remains stable.¹²

Cellular Water Functions

Water has both physical as well as biochemical importance to the cell. Physically, it helps structurally to maintain the size and shape of the cell and internal structures,¹³ as well as acting as a mode of transport. Biochemically, it provides the environment for cellular processes and helps prevent rapid temperature changes.

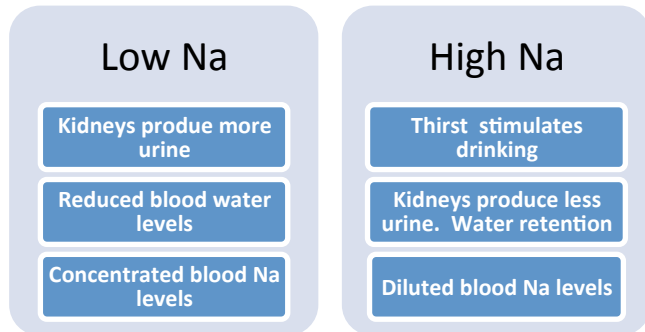
Regulatory Feedback Mechanisms

Electrolyte balance is regulated by the kidneys and hormones such as anti-diuretic hormone, aldosterone and parathyroid hormone. Whenever the sodium level dips too low, the kidneys are stimulated to produce more urine, which restores the balance by lowering the amount of water in the blood. And when sodium levels get too high, thirst develops,

Hydration: More Than Just Water

By Jan Clementson

stimulating the person to drink. Anti-diuretic hormone is also secreted by the brain in response to thirst that causes the kidneys to produce less urine. Together, these effects result in dilution of the sodium and restoration of balance.



Electrolyte Imbalances

The most common electrolyte imbalances are in sodium and potassium. Serious disturbances, such as in dehydration and over-hydration, can have serious consequences leading to cardiac and neurological complications. Symptoms can range in severity from skeletal muscle cramps, muscle fatigue, tachycardia (rapid heartbeat), loss of consciousness and shock, and can result in a medical emergency. Exercise-associated hyponatremia (low blood sodium levels) has emerged as the most common life-threatening complication of endurance exercise.¹⁴

Dehydration Signs

Fluid intake is regulated by thirst. However, the sensation of thirst is actually being triggered after the fluids in the body have been lowered. Ignoring thirst can lead to dehydration. Other indicators include increased urination and sweating; constipation; sudden feelings of hunger or fatigue; dry skin; joint pain; dry mouth and eyes; and fluid retention. Muscle cramps are more common where large sweat sodium losses occur.¹⁵



Over-Hydration and Water Intoxication

Over-hydration occurs when there is an increase in water concentration inside of the cell. This usually results from a significant sodium depletion (such as sweating for several hours during a marathon), coupled with a high water intake and an inadequate sodium intake, leading to a sodium deficit. The decrease in sodium concentration in body fluids lowers fluid osmotic pressure (the pressure required to prevent the inward flow of water) and results in an increased water flow into the cell.



Such over-hydration is disruptive to nerve cell function and can produce symptoms of light-headedness or mild vertigo; and a loss of blood volume as water moves out of the plasma into the cells, which can lead to circulatory shock. Severe over-hydration is known as water intoxication. It produces neurological symptoms ranging from disorientated behaviour to convulsions, coma and death.

SPECIAL ENVIRONMENTAL CONDITIONS

Hot and Humid Environments

The risk for dehydration and heat injury increases dramatically in hot, humid environments.¹⁶ When the ambient temperature exceeds body temperature, heat cannot be dissipated by radiation, whilst sweat evaporation is also substantially reduced.

Cold Environments

It is possible for dehydration to occur in cool or cold weather.¹⁷ Factors contributing to dehydration include respiratory fluid losses, as well as sweat losses that occur when wearing insulated clothing during exercise. Low rates of fluid ingestion also occur when an athlete is chilled.

Altitude

Fluid losses beyond those associated with any exercise performed may occur at altitudes >2,500m as a result of mandatory diuresis, high respiratory

Hydration: More Than Just Water

By Jan Clementson

water losses and decreased appetite.¹⁸ Respiratory water losses may be as high as 1.9 L per day in men and 0.85 L per day in women.¹⁹ Total fluid intake at high altitude approaches 3-4 L per day to promote optimal kidney function and maintain urinary output in adults.²⁰



FLUID AND ELECTROLYTE RECOMMENDATIONS Before Exercise

Dehydration prior to exercise will potentiate the reductions in performance associated with the heat.²¹ Pre-exercise sodium loading can aid fluid balance and endurance in the heat.²² High sodium fluids prior to exercise can decrease cardiovascular and thermal strain and enhance exercise capacity.²³

At least 4 hours before exercise, drink about 5-7 mL/kg of body weight of fluid containing water and sodium/electrolytes.²⁴ This would allow enough time to optimise hydration status for excretion of any excess fluid as urine. Hyper-hydration will greatly increase the risk of having to empty the bladder during exercise.²⁵

During Exercise

Sweat rates will vary according to ambient temperature, humidity, body weight, genetics, heat acclimatisation state and metabolic efficiency.²⁶ In addition to water, sweat also contains sodium. The average concentration of sodium in sweat is about 1 g/L (although concentrations vary widely).²⁷ Only modest amounts of potassium and small amounts of other electrolytes are lost in sweat.

The amount and rate of fluid replacement is dependent upon the individual's sweat rate, exercise duration and opportunities to drink.²⁸ Electrolyte drinks can help sustain fluid balance and endurance exercise. Relatively small amounts of sodium in a sports drink consumed at a rate equal to body mass

change can prevent the decrease in plasma sodium concentration typically seen during prolonged exercise.²⁹ However, fluid balance during exercise is not always possible because sweat rates exceed gastric emptying rates that limit fluid absorption.

After Exercise

Since many athletes do not consume enough fluids during exercise to balance fluid losses, they complete their exercise session dehydrated. Athletes often fail to completely replace body fluid losses during the first few hours of recovery.³⁰ Rapid and complete recovery from exercise can be accomplished by drinking at least 450-674 mL of fluid for every 0.5 kg of body weight lost during exercise.³¹ Electrolyte drinks and salty foods at meals/snacks will help replace fluid and electrolyte losses.³²



Positive rehydration only occurs with electrolyte replacement and where the volume of fluid consumed is greater than the sweat loss – up to 150% to compensate for fluid loss due to urine production during rehydration.³³ Ingestion of plain water does not result in proper rehydration because it causes a rapid fall in plasma sodium concentrations, which stimulates urine output.³⁴ During recovery, sodium consumption in fluids not only retains ingested fluids but also helps to stimulate the thirst sensation.³⁵

ELECTROLYTE REPLACEMENT Sodium

Sodium is the critical electrolyte, particularly for athletes with high sweat losses in heat stress environments.³⁶ Normal daily salt intake from food is about 6-8 g/day for the UK population.³⁷ For athletes with large sweat losses, ingestion of up to 15 g/day of sodium chloride can be required to restore balance.³⁸ A typical teaspoon of salt will contain approximately 5g. For athletes with high sweat losses and those in hot environments, up to an additional 2 teaspoons of salt per day may be needed for proper rehydration.

Hydration: More Than Just Water

By Jan Clementson

DIY Electrolyte Replacement

Adding salt to food or to water can be a simple way of helping to restore fluid balance. Use natural sea salt or Herbamare salt (sea salt with herbs) to add to water as they contain other minerals in addition to sodium. Herbamare is by far the most palatable. A homemade electrolyte drink can be made using water, sugar, salt, salt substitute for potassium and baking soda (for biocarbonate).

Commercial Sports Drinks

Most major commercial sports drinks contain only small amounts of sodium.³⁹ Soft drinks, which are most commonly used, contain virtually no sodium and are not suitable for rehydration.⁴⁰ Coconut water - a natural, refreshing, sweet and palatable drink - can be used as a rehydration fluid as it contains sodium, potassium, chloride and glucose.⁴¹ However, it has a low sodium and high potassium content, thereby reducing its effectiveness as a rehydration drink. Additional salt would be needed.

Electrolyte Nutritional Supplements

Until recently, the available electrolyte nutritional supplements have been limited and the quality poor. The most favoured, and probably the best, has been the **Elete Electrolyte** product. However, the sodium content is too low and is lower than the potassium content. It does have the advantage of being an **Informed Sports** product, which means that it has been tested for banned substances according to WADA regulations. Hence, it is suitable for those athletes who are subject to drugs testing.

New to the supplement market is **BioCare's Refresh Intensive** powder, which has been designed specifically as a proper electrolyte product. It contains all the main electrolytes and has a higher sodium:potassium ratio. It also has the added benefit of high levels of magnesium, B vitamins and creatine, which are used for cellular energy and are often depleted after exercise. Furthermore, these nutrients are in an antioxidant berry base, which helps to neutralise the free radicals generated during exercise. At present, it is not yet Informed Sports approved and hence not drugs tested, though this may change in the near future. For further information, check out www.biocare.co.uk.

GENERAL ACTION POINTS

1. Average daily water requirements per day: M = 2.9 L; W = 2.2 L. (incl 1 L from food)
2. Do not ignore thirst – you are already dehydrated at this stage.
3. Aim to start each bout of exercise in a fluid replete state.
4. Consume electrolytes, or at least salt, to retain water and prevent over-hydration.
5. The more you sweat, the more water and sodium you will need.
6. Increase your hydration in hot, humid and cold environments, and when at altitude.
7. Ensure complete rehydration after exercise, which must include electrolytes or salt.

EXERCISE HYDRATION GUIDELINES

Before Exercise

- 4 hrs prior to exercise drink 5-7 mL/kg of body weight of water & sodium/electrolytes

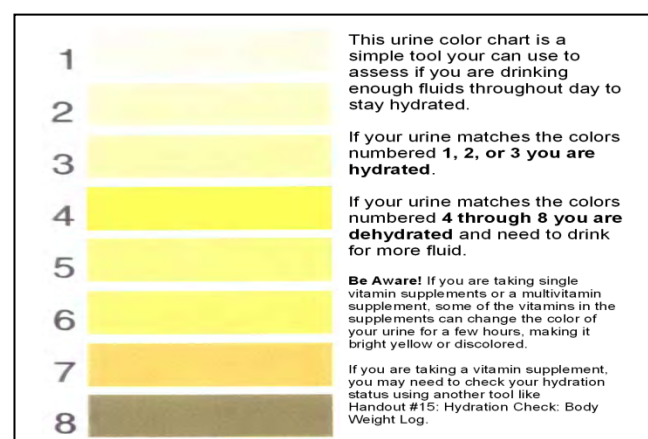
During Exercise

- 1.0-2.5 L/hr fluid & 1 g/L salt lost
- Drink same amount of fluid, plus electrolytes or 1/5 teaspoon salt

After Exercise

- Drink 450-674 mL fluid for every 0.5 kg of body weight lost.
- Electrolytes or 1-2 tsp. salt essential

Quick Reference Urine Hydration Chart



The darker the colour, the greater the dehydration.

Water balance and electrolytes are inseparable

Jan Clementson has a First Class Honours Degree in Nutritional Medicine and works as a Clinical Nutrition Advisor for BioCare Ltd

Hydration: More Than Just Water

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References

¹ United Nations. Un.org. 2005-03-22.

² CIA – The World Fact Book. Central Intelligence Agency.

³ Baroni L et al (2007). Evaluating the environmental impact of various dietary patterns combined with different food production systems. **European Journal of Clinical Nutrition**, 61(2): 279-286.

⁴ Benelam B & Wyness L (2010) Hydration and Health: a review. British Nutrition Foundation Bulletin. 35: 3-25.

⁵ Utz J, M.D. What percentage of the human body is composed of water? The MadSci Network.

⁶ Kleiner S M (1999) Water: an essential but overlooked nutrient. J Am Dietetic Assoc, 99(2): 200-206.

⁷ Kleiner S M (1999) Water: an essential but overlooked nutrient. J Am Dietetic Assoc, 99(2): 200-206.

⁸ Von Duvillard S P et al. Fluids and hydration in prolonged endurance performance. Nutrition 2004; 20 (7-8): 651-6.

⁹ Maughan R J & Shirreffs S M (1997). Factors influencing the restoration of fluid and electrolyte balance after exercise in the heat. **Br J Sports Med**, 31: 175-182.

¹⁰ Von Duvillard S P et al. Fluids and hydration in prolonged endurance performance. Nutrition 2004; 20 (7-8): 651-6.

¹¹ Maton A et al (1997). **Cells Building Blocks of Life**. USA, New Jersey: Prentice Hall.

¹² Textbook of Medical Physiology, Guyton, 7th Ed. 1986, W B Saunders Company.

¹³ Waterson J G (1987). A role for water in cell structure. BioChem J, 248: 615-617.

¹⁴ Hew-Butler T et al (2008). Osmotic and nonosmotic regulation of arginine vasopressin during prolonged endurance exercise. **J Clin Endocrinol Metab**, 93(6): 2072-2078.

¹⁵ Sawka M N et al (2007). American College of Sports Medicine position stand. Exercise and fluid replacement. **Med Sci Sports Exerc**, 39: 556-572.

¹⁶ Armstrong L E et al (2007). American College of Sports Medicine position stand. Exertional heat illness during training and competition. **Med Sci Sports Exerc**, 39: 556-572.

¹⁷ Castellani J W et al (2006). American College of Sports Medicine position stand: prevention of cold injuries during exercise. **Med Sci Sports Exerc**, 38: 2012-2029.

¹⁸ Dietitians of Canada and American College of Sports Medicine. Nutrition and Athletic Performance: Joint Position Paper.

¹⁹ Armstrong L (2007). Performing in Extreme Environments. USA, Champaign IL: Human Kinetics.

²⁰ Armstrong L (2007). Performing in Extreme Environments. USA, Champaign IL: Human Kinetics.

²¹ Maughan R J & Shirreffs S M (1997). Factors influencing the restoration of fluid and electrolyte balance after exercise in the heat. **Br J Sports Med**, 31: 175-182.

²² Sims S T et al (2007). Pre-exercise sodium loading aids fluid balance and endurance for women exercising in the heat. **J Appl Physiol**, 103: 534-541.

²³ Berger N J A et al (2006). Influence of acute plasma volume expansion on VO₂ kinetics: VO₂ and performance during high-intensity cycle exercise. **J Physiol**, 101: 707-714.

²⁴ Dietitians of Canada and American College of Sports Medicine. Nutrition and Athletic Performance: Joint Position Paper.

²⁵ Sawka M N et al (2007). American College of Sports Medicine position stand. Exercise and fluid replacement. **Med Sci Sports Exerc**, 39: 556-572.

²⁶ Dietitians of Canada and American College of Sports Medicine. Nutrition and Athletic Performance: Joint Position Paper.

²⁷ Dietitians of Canada and American College of Sports Medicine. Nutrition and Athletic Performance: Joint Position Paper.

²⁸ Sawka M N et al (2007). American College of Sports Medicine position stand. Exercise and fluid replacement. **Med Sci Sports Exerc**, 39: 556-572.

²⁹ Anastasiou C A et al (2009). Sodium replacement and plasma sodium drop during exercise in the heat when fluid intake matches fluid loss. **Journal of Athletic Training**, 44(2): 117-123.

³⁰ Park S G et al (2012). Effects of rehydration fluid temperature and composition on body weight retention upon voluntary drinking following exercise-induced dehydration. **Nutrition Research and Practice**, 6(2): 126-131.

³¹ Dietitians of Canada and American College of Sports Medicine. Nutrition and Athletic Performance: Joint Position Paper.

³² Sawka M N et al (2007). American College of Sports Medicine position stand. Exercise and fluid replacement. **Med Sci Sports Exerc**, 39: 556-572.

³³ Maughan R J & Shirreffs S M (1997). Factors influencing the restoration of fluid and electrolyte balance after exercise in the heat. **Br J Sports Med**, 31: 175-182.

³⁴ Saat M et al (2002). Rehydration after exercise with fresh young coconut water, carbohydrate-electrolyte beverage and plain water. **J Physiol Anthropol**, 21(2): 93-104.

³⁵ Park S G et al (2012). Effects of rehydration fluid temperature and composition on body weight retention upon voluntary drinking following exercise-induced dehydration. **Nutrition Research and Practice**, 6(2): 126-131.

³⁶ Sawka M N et al (2007). American College of Sports Medicine position stand. Exercise and fluid replacement. **Med Sci Sports Exerc**, 39: 556-572.

³⁷ Maughan R J & Shirreffs S M (1997). Factors influencing the restoration of fluid and electrolyte balance after exercise in the heat. **Br J Sports Med**, 31: 175-182.

³⁸ Maughan R J & Shirreffs S M (1997). Factors influencing the restoration of fluid and electrolyte balance after exercise in the heat. **Br J Sports Med**, 31: 175-182.

³⁹ Maughan R J & Shirreffs S M (1997). Factors influencing the restoration of fluid and electrolyte balance after exercise in the heat. **Br J Sports Med**, 31: 175-182.

⁴⁰ Park S G et al (2012). Effects of rehydration fluid temperature and composition on body weight retention upon voluntary drinking following exercise-induced dehydration. **Nutrition Research and Practice**, 6(2): 126-131.

⁴¹ Saat M et al (2002). Rehydration after exercise with fresh young coconut water, carbohydrate-electrolyte beverage and plain water. **J Physiol Anthropol**, 21(2): 93-104.