Hydration
Beneficial Roles of Citrus
Executive Summary

Sandy Barros, Filomena Valim and John Zhang

Water balance is extremely important in day-to-day life in the maintenance of good health and the prevention of chronic disease. Water is lost from the body in varying amounts via a number of different routes. The total daily water loss is about 2.5 L, but this varies greatly between individuals and depends on environmental conditions.

Dehydration is associated with a number of negative effects on health and well-being. There is increasing evidence that even mild dehydration, defined as a 1-2% loss in body mass caused by fluid loss affects the onset of various chronic diseases such as kidney stones, urinary tract infection, hypertension, pulmonary disorders and even coronary heart disease.

Given the increasing awareness of the importance of hydration for health and performance, a significant amount of research has provided new insight into several key aspects of hydration.

Populations at particular risk of dehydration and its sequel include the very young and the elderly. One of the factors for the propensity of dehydration and alteration in water homeostasis in older adults is that the sense or perception of thirst is lessened with age, leading them to not drinking enough to rehydrate themselves. Healthy children may also be at risk of dehydration if there is a sudden increase in water loss for any reason, and physically active children will be at particular risk during periods of warm weather.

Adequate hydration is essential for optimum performance and to ensure that athletes do not incur heat-related illness. A primary role of ingesting carbohydrates in a fluid replacement beverage is to maintain optimal blood glucose concentration. Athletes should begin consuming fluids and carbohydrates immediately after exercise to help the body replace fluids lost in sweat and to replenish glycogen, which is the main source of muscle glucose.

The addition of carbohydrates to a fluid replacement solution can enhance intestinal absorption of water. The inclusion of glucose, sucrose and complex carbohydrates in fluid replacement solutions has equal effectiveness in increasing exogenous carbohydrate oxidation, delaying fatigue, and improving performance. Because fructose is converted slowly to blood glucose, it should not be the predominant carbohydrate, as it will not improve performance. There is little physiological basis for the presence of sodium in an oral rehydration solution for enhancing intestinal water absorption as long as sodium is sufficiently available in the gut from the previous meal or in the pancreatic secretions. In most cases, sodium losses which occur from sweating during exercise (less than 4-5 hours) can be replenished by normal dietary intake.

During exercise, there is an increase in oxygen uptake in various organs, particularly in the skeleton muscle. Excess reactive oxygen species (ROS) release during exercise may have adverse implications on health and performance. Dietary antioxidants, such as vitamin C and flavonoids, may be helpful in reducing excess ROS.

Among the readily available beverages to fulfill hydration requirements orange juice is a healthy, flavorful, and nutrient-dense beverage. In addition, Florida orange juice is a convenient, fat and sodium free food composed of about 88% water plus natural vitamins, minerals and flavonoids. Orange juice contains about 10% carbohydrates, which includes one part of glucose, two parts of sucrose and only one part of fructose, and therefore should not be discounted as a fluid replacement beverage before, during and after exercise.

For a more detailed and referenced review of this topic, please continued reading below

Hydration
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Literature Review

Sandy Barros, Filomena Valim and John Zhang

1- Introduction:

Water is the main constituent of the human body, accounting for about 50-60% of total body mass. It plays an essential role in circulatory function, chemical reactions involved in energy metabolism, elimination of waste products and maintenance of the body temperature and plasma volume (Aoi et al., 2006).

The turnover rate of water exceeds that of most other body components. For the sedentary individual living in a temperate climate, daily water turnover is about 2,000–3,000 mililiters (mL). This results in about 5–10% of the total body water content renewed every day (Maughan, 2003).

Water is lost from the body in varying amounts via a number of different routes: the main ones are urine (about 1,400 mL), feces (200 mL), insensible losses from the lungs (400 mL), and via the skin (500 mL). The total daily water loss is about 2,500 mL, but this varies greatly between individuals and depends on the environmental conditions. When the air is dry, water loss from the skin and lungs is increased because of the increased vapor pressure gradient, and more water is also lost by these routes in hot weather (Maughan, 2003).

The amount of water lost in the urine depends very much on the volume of fluid consumed and on the total losses by other routes. It also depends on the solute content of the diet, and high intakes of salt or protein will increase the daily fluid requirement because of the limited capacity of the kidneys to concentrate the urine. If water intake is restricted, the kidneys will conserve water by producing more concentrated urine. The body cannot store excess water, so the kidneys will get rid of any temporary excess by producing a large volume of dilute urine (Engell & Hirsch, 1991).

When the body temperature rises due to intense exercise or a high ambient temperature, sweating occurs in order to loose heat, leading to the loss of water and electrolytes such as sodium. This loss of body fluid impairs thermoregulation and the circulatory system.

Dehydration is associated with a number of negative effects on health and well-being. Acute changes in the hydration status are commonly designated as dehydration or rehydration. Differences in hydration status are called hypohydration (a water deficit), euhydration (being in water balance), and hyperhydration (a water excess). Euhydration, however, is not a steady state, but rather a dynamic state in that one continuously loses water from the body and there may be a time delay before replacing it or, one may take a slight excess of water and lose it (Greenleaf, 1992).

Severe dehydration is detrimental to health, and is associated with compromised cardiovascular function, renal impairment, weakness and lassitude, and a number of diffuse symptoms including headache, nausea and general malaise (Maughan, 2003).

There are some negative subjective symptoms associated with even modest levels of dehydration. Self-ratings of alertness and ability to concentrate decline progressively when fluid intake is restricted to induce body mass deficits of even as little as 1-2%. At the same time, ratings of tiredness and headache increase (Maughan, 2003). There are also some indications in the published literature that cognitive function, assessed by decision making and reaction time tests, is also impaired at relatively low levels of dehydration (Gopinathan et al., 1988).

Populations at particular risk of dehydration and its sequel include the very young and the elderly (Maughan, 2003). Involuntary dehydration occurs most often in adults over 70 years of age under essentially nonstressful conditions. Coupled with physical stresses, such as acute illness, infections, fever, or diabetes, older people may be at greater risk for clinically significant dehydration. Studies of older individuals suggest that both community-dwelling and inpatient elderly adults do indeed experience chronic mild dehydration (Suhr et al., 2004).

In spite of great improvements in sanitation and in the availability of rehydration solutions, dehydration resulting from infectious diarrheal disease remains one of the largest single causes of death among young children, being responsible for about 1.5 million deaths annually around the world (WHO, 2002). Healthy children may also be at risk of dehydration if there is a sudden increase in water loss for any reason, and physically active children will be at particular risk during periods of warm weather. The large surface area to volume ratio of children relative to adults means that they gain more heat through the skin when the environmental temperature exceeds skin temperature (Bar-Or, 1989). In order to prevent an excessive rise in body temperature, there is an increased loss of water from the body and children may need encouragement to drink when losses are high.

It is well recognized that oral rehydration solutions (ORS) can be used successfully for the treatment of dehydration from diarrhea and vomiting (Nijssen-Jordan, 1997). There is a recommendation by the Canadian Pediatric Society that parents should give only commercially available ORS without flavoring to children. However, many parents state they cannot get their children to drink ORS. One of the strategies used by physicians and parents to encourage the intake of ORS has been to flavor the ORS with the child's favorite juice. The authors found that fruit juices including orange juice at a ratio not greater than 4:1 (ORS:fruit juice) can be added to ORS without significantly altering electrolyte composition and osmolality[1] (Nijssen-Jordan, 1997).

The older adult is more likely to have problems maintaining water homeostasis and is more susceptible to dehydration for several reasons. As one ages, there is less total body water due to a decrease in lean body mass and an increase in percentage of body fat. The percentage of body mass as water declines from 60% of body weight in young men to as little as 45% in elderly women (Davis & Minaker, 1994). Structural and functional changes occur as the kidneys age. Nephrons[2] are lost and/or the remaining ones perform less effectively, and the glomerular filtration rate[3] decreases. Lessened responsiveness to hormonal signals causes the kidneys to function less efficiently in concentrating urine and correcting water loss. Another factor in the propensity for dehydration and alteration in water homeostasis in older adults is that the sense or perception of thirst is lessened with age, leading them to not drinking enough to rehydrate themselves (Davis & Minaker, 1994).

Under normal circumstances, age-related changes do not result in water imbalance, but because the functional reserve of older adults is limited, major stresses can easily challenge systems causing fluid problems. Illnesses and acute and chronic infections, as well as symptomology of fever, vomiting, and diarrhea, are commonly associated with dehydration. These illnesses and infections include diabetes, influenza, pneumonia, respiratory infections, gastroenteritis, urinary tract infections and infections from pressure sores (Sheehy et al., 1999).

2- Human Water Needs:

According to the Food and Nutrition Board of the Institute of Medicine (F&NB, 2004), normal water needs range widely due to numerous factors (e.g. metabolism, diet, climate, clothing). The F&NB bases water needs on adequate intake (AI). The AI is based on experimentally derived intake levels that are expected to meet nutritional adequacy for essentially all members of a healthy population.

There is no "gold standard" to measure hydration status in all circumstances. Thus, several indicators are currently in use: parameters of water balance (e.g., water intake), changes in body weight

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[1] Osmolality: number of dissolved particles in a fluid.
[2] Nephron: functional unit of the kidneys consists of a filtering unit of tiny blood vessels called a glomerulus attached to a tubule.
[3] Glomerular filtration rate: a measurement of kidney function

or total body water, plasma indicators (e.g., serum osmolality), and urine indicators (e.g., volume, color, osmolality, free water reserve) (Manz & Wentz, 2003; FN&B, 2004).

Serum osmolality is a widely used index of hydration status, because extracellular fluid osmolality stimulates important fluid regulatory mechanisms. Indeed, some investigators consider it to be the only valid index of hydration status (Moran et al., 2004).

Measurement of urine osmolality (Uosm) has recently been an extensively studied parameter as a possible hydration status marker (Shirreffs & Maughan, 1998). Uosm, a measure of total urine solute content, is affected by all dissolved particles in a known volume of fluid. Osmolality is expressed as mOsm/kg. Analyses require an osmometer and a trained laboratory technician and are time consuming. Because osmolality is the most accurate measurement of total solute concentration, it provides the best measurement of the kidney's concentrating ability (Dufour, 2001). However, because urine properties are regulated by several interactive mechanisms, and because water turnover is constantly changing, no universally accepted technique exists to determine whether humans are hypohydrated, euhydrated, or hyperhydrated.

There are remarkable differences in 24-h Uosm between subjects and groups mainly caused by age, individual character, renal solution excretion, gender and cultural context. For example, mean Uosm (mOsm/kg, assuming 1 gram (g) of water equals 1 mL of urine) in healthy subjects from Germany is 801, France 755, USA 649, and Belgium 650 (Manz & Wentz, 2003).

Fluid balance studies show that daily water needs increase with age from early infancy (~0.6 liters (L)) through childhood (~1.7 L) (Goellner et al., 1981; Ballauff et al., 1988). For adults, the daily water needs of men approach 2.5 L if sedentary, and increase to about 3.2 L if performing modest physical activity, while more active adults living in a warm environment have daily water needs of about 6 L (Welch et al., 1958).

Examination of water turnover studies indicates that daily water turnover is 3.3 and 4.5 L for sedentary and active men, respectively (Fusch et al., 1996; Raman et al., 2004). Higher values, greater than 6 L, have been reported for more active populations (Ruby et al., 2002).

The Third National Health and Nutrition Examination Survey (NHANES III 1988-1994) obtained total daily water intakes data from a large population (n = 27,744). The results indicated that for children and adults, about 80% of the total daily water intake is obtained from beverages and about 20% from food (F&NB, 2004). Most importantly, the NHANES data indicate that, for all age groups (12

– 71+ years) and levels of consumption, everyone involved in the study was in water balance (i.e., they had normal plasma osmolality).

The NHANES III results were consistent with data obtained from previous water balance and water turnover studies. For adult males, the total daily water intake was about 3.31 L for 5th decile and increased to over 6 L for the 10th decile.

A recent publication by Popkin et al. (2006) summarized the results from The Beverage Guidance Panel, which was assembled to provide guidance on the relative health and nutritional benefits of various beverage categories. The Panel recognizes that it is not possible to define a set amount of water for each person because the water needs depend on overall diet and the water obtained from foods. However, data from the Institute of Medicine (IOM) report on water and electrolytes of a healthy menu that fulfills all nutrients requirements for a healthy man, shows that a 6 oz glass of orange juice would contribute about 6% of the required fluid intake. According to the Panel's experts the key message is that all the suggested beverages combined contribute up to 14% of the total caloric intake. The Panel stated that daily intake of up to 8 oz of 100% fruit juices, such as orange juice, would be acceptable within their recommendation of calories obtained from beverages and energy intake for a 2,200 kcal diet.

3- Thirst:

Thirst is the conscious perception of the need to ingest fluids that is stimulated by alterations in body fluid composition and in blood volume or pressure. Although the pathways responsible for the conscious perception of thirst are not fully delineated, the behavioral response of drinking in response to thirst is thought to be due to the activation of osmoreceptors in the hypothalamus[4] as well as other influences from the limbic system[5] and the cerebral cortex (Grossman, 1990; Porth & Erickson, 1992).

It has been suggested that thirst and dry mouth are not only associated with dehydration but may result from iatrogenic[6] causes. Furthermore, thirst may be associated with perception of a dry mouth and thus not centrally mediated by dehydration. Termination of thirst and cessation of drinking are influenced by oropharageal cues and gastric distention. These influences are not long-acting, however, it

[4] Hypothalamus: regulates certain metabolic processes and other autonomic activities
[5] Limbic system: the limbic system influences the formation of memory by integrating emotional states with stored memories of physical sensations.
[6] Iatrogenic: caused by or resulting from medical treatment.

is only when plasma osmolality and/or blood pressure returns to normal that the conscious perception of the need to drink is eliminated.

4- Mild Dehydration:

There is increasing evidence that even mild dehydration, defined as a 1-2% loss in body mass caused by fluid loss, impairs exercise performance, affects overall health in the elderly and increases the risk of urinary stone disease (Kleiner, 1999).

Many chronic diseases have multifactorial origins. In particular, differences in lifestyle and the impact of environment are known to be involved and constitute risk factors that are still being evaluated. Water is quantitatively the most important nutrient. There is increasing evidence that mild dehydration may also account for many morbidities[7] (Manz & Wentz, 2005).

4.1- Health Effects of Mild Dehydration on Various Chronic Diseases:

4.1.1- Urolithiasis (kidney stones)

A high fluid intake is the first general advice given to patients in the prevention of kidney stone recurrence, irrespective of stone composition (Honow et al., 2003). An increase of fluid intake is associated with a reduced risk for kidney stone formation, reported by several authors (Curhan et al., 1996, 1998: Hesse & Siener, 1997). Urine dilution causes a lowering of the concentration of constituent ions and thus a decrease of the super-saturation of the stone-forming salts. Depending on the stone composition, several fluids have been found to be suitable to decrease stone formation, such as mineral water, orange juice, apple juice, and herbal teas. Alkalizing beverages such as orange juice are highly effective in the metaphylaxis[8] of calcium oxalate, uric acid and cystine stone formation. Citrus fruits and juices like grapefruit juice and orange juice are a natural rich source of citrate; they contain about 10 mg of citric acid/g. The high content of citric acid causes an increased citric acid excretion and is responsible for the alkalinizing effect. Calcium oxalate is the most common crystal in kidney stones in the United States, accounting for about 80% of all stones analyzed (Coe et al., 1992). Urinary citrate is a physiologic defense mechanism against calcium stones. It binds calcium in the soluble calcium citrate salt, thus depriving urinary oxalate of calcium and preventing the formation or continued growth of an insoluble calcium oxalate crystal.

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[7] Morbidities: incidence or prevalence of diseases.
[8] Metaphylaxis: a comprehensive and long-term regimen which should reduce the rate of recurrence of a medical condition.

Wabner & Pak (1993) examined the value of orange juice consumption in kidney stone prevention in eight healthy men and three men with documented low urinary citrate that resulted in kidney stone formation. Compared to potassium citrate tablets at the same content of potassium, orange juice delivered an equivalent alkali load and urinary alkalization.

In 2004, a prospective study in 25 patients with a history of kidney stones showed that an increased total fluid intake and limited intake of salt and protein resulted in an increased urine volume and a decreased number of stones (Carvalho et al., 2004).

A recent study by Odvina (2006) compared the effect of orange juice and lemonade on acid-base profile and urinary stone risks. The study suggests that orange juice consumption could result in biochemical modification of stone risk factors, however, additional studies are needed to evaluate its role in long-term prevention of recurrent urolithiasis.

4.1.2 - Urinary Tract Infection (UTI)

In two prospective studies of girls, recurrent UTI was associated with infrequent urine voiding and poor fluid intake (Mazzola et al., 2003; Stauffer et al., 2004). A study in adults with urinary catheters showed that low urine output was significantly related to UTI (Wilde & Carrigen, 2003). Several expert committees recommend a high fluid intake in patients with UTI.

4.1.3- Bronchopulmonary Disorders

The basic physiologic mechanisms in lung and airways demonstrate a critical role of water transport and local hydration status of mucus. Except for exercise asthma, more research is needed to confirm or refute chronic mild hypohydration as a risk factor for bronchopulmonary disorders (Kalhoff, 2003). Nevertheless, several expert committees recommend a high fluid intake in bronchopulmonary disorders. Moloney et al. (2002) observed the dehydration of the expired air in asthmatic patients in the emergency department compared to non-asthmatic patients.

4.1.4- Hypertension

In diabetic patients, lower urine flow and sodium excretion rates are associated with higher blood pressure during the day and a reduced fall in blood pressure at night (Bankir et al., 2002). In a study of 1,688 healthy men, a low urine production day-to-night ratio was not associated with hypertension (Blanker et al., 2002).

In one study, eight male hypertensive volunteers and eight controls were exercised in a hot environment with or without water ingestion. In the hypertensive men, water ingestion increased exercise-related differences in their systolic (+21%) and diastolic blood pressures (+20%) when compared to the control subjects (Ribeiro et al., 2004).

4.1.5- Fatal Coronary Heart Disease

In the Adventist Health Study (Chan et al., 2002), a high intake of water was associated with a reduced risk of fatal cardiac heart disease. Another study showed that Japanese taxi drivers with an increased risk of cardiac heart disease had increased blood coagulation and hematocrit, probably due to a low water intake at night (Hattori & Azani, 2001).

4.2- Impact of Mild Dehydration on Cognitive Function:

Dehydration is a reliable predictor of impaired cognitive status. Objective data, using tests of cortical function, support the deterioration of mental performance in mildly dehydrated young adults. Dehydration frequently results in delirium as a manifestation of cognitive dysfunction (Wilson & Morley, 2003).

In a study of young healthy Indian males acclimated to tropical weather, dehydration of 2 to 3% of body weight resulted in poor performance of concentration and psychomotor processing speed (Sharma et al., 1986).

Similar results were reported by Gopinathan et al. (1988) in a sample of heat-acclimated soldiers dehydrated via exercise. Short-term memory, attention, and psychomotor processing speed deteriorated as the degree of dehydration increased, particularly beyond 2% body weight loss.

In a study conducted by Suhr et al. (2004), 28 participants ranging in age from 50 to 82 years, most of whom were college educated were recruited to determine whether lower levels of hydration would be related to slowed psychomotor processing speed and poor performance on measures of attention and memory. The results showed that hydration status was significantly related to performance in psychomotor processing speed and attention/memory skills. Individuals who were less hydrated performed more slowly across several measures of psychomotor processing speed and more poorly on attention/memory tasks, even after controlling for the effects of demographic variables and blood pressure on cognition.

4.3- Water Overconsumption and Intoxication:

Water intoxication can lead to Hyponatremia, an overdilution of sodium in the blood plasma (> 135 mmol/L), which can be life threatening. Hyponatremia can occur from over excessive fluid intake, under-replacement of sodium, or both during or after prolonged endurance athletic events. The signs and symptoms of hyponatremia depend upon the rapidity with which the serum sodium declines, as well as on the absolute levels. Initial symptoms typically include lightheadness, sometimes accompanied by nausea, vomiting, headache and/or malaise. Plasma sodium levels below 100 mmol/L frequently results in cerebral edema, seizures, coma, and death within a few hours of drinking excess water. Progression from mild to severe symptoms may occur rapidly as the water continues to enter the body from the intestines or intravenously (F&NB, 2004). Several deaths due to water intoxication have been documented. Most recently, a lady from California, who was participating in a contest involving drinking large quantities of water without urinating died from water intoxication.

5- Dehydration and exercise performance:

Although the physiological consequences of dehydration due to the sweat loss that occurs during exercise have been the focus of much attention, there has been relatively little scientific interest in the effects of a fluid deficit incurred prior to exercise. Both of these situations are common in sports. Individuals who begin exercise with a fluid deficit will not perform as well as if they were fully hydrated (Maughan, 2003).

An impaired performance is observed whether the exercise lasts a few minutes, or whether it is more prolonged, although muscular strength appears to be relatively unaffected, and tasks with a large aerobic component are affected to a greater extent than those that rely primarily on anaerobic metabolism (Sawka & Pandolf, 1990).

In exercise tests lasting more than a few minutes, reductions in performance are apparent at modest levels of body water loss amounting to 1-2% of the pre-exercise body mass. For the average young male, body water accounts for about 60% of total body mass, so these levels of hypohydration amount to about 2-3% of total body water. It was reported by Adolph et al. (1947) that subjects do not report a sensation of thirst until they have incurred a water deficit of about 2% of body mass. This suggests that athletes living and training in the heat may not be aware that they have become dehydrated to a level sufficient to affect performance adversely.

Fluid losses due to sweating are distributed in varying proportions among the various body compartments: plasma, extracellular water and intracellular water. The decrease in plasma volume that accompanies dehydration may be of particular importance in influencing work capacity. Blood flow to the muscles must be maintained at a high level to supply oxygen and substrates, but a high blood flow to the skin is also necessary to convect heat from the active muscles and the body core to the body surface where it can be dissipated (Nadel, 1989).

When the ambient temperature is high and blood volume has been decreased by sweat loss during prolonged exercise, there may be difficulty in meeting the requirement for a high blood flow to both these tissues. Data have suggested that dehydration may cause a reduction in the blood flow to exercising muscles as well as to the skin (Gonzales-Alonso et al., 1998).

Montain & Coyle (1992) demonstrated an increase in core (organs) temperature and heart rate and a decrease in cardiac stroke volume[9] during prolonged exercise are graded according to the level of hypohydration reached. They also showed that the ingestion of fluids during exercise increases skin blood flow, and therefore thermoregulatory capacity, independent of increases in the circulating blood volume.

Adequate hydration is essential for optimum performance and to ensure that athletes do not incur heat-related illness. Except under unusual circumstances, hydration status is largely a function of voluntary fluid intake. However, the amount of fluid consumed by athletes frequently does not adequately match sweat losses. This failure to adequately replace lost fluid levels was described as "voluntary dehydration" by Rothstein at al. (1947).

Athletes should begin consuming fluids and carbohydrates immediately after exercise to help the body replace fluids lost in sweat and to replenish muscle glycogen stores. When the glycogen content of the exercising muscles is very low, it is not possible to exercise at high intensities, although low intensity exercise is possible, with the muscles relying mainly on fat as a fuel (Schedl et al., 1994).

A 100% pasteurized orange juice contains approximately 10% carbohydrates, however commercially available reduced calorie orange juice beverages contain between 5 and 7% carbohydrates while still containing significant quantities of potassium and other health vitamins and minerals. Orange juice can further be utilized as a replacement fluid in preparation for, during and after moderate athletic competitions and exercise.

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[9] Cardiac stroke volume: the volume of blood ejected from a ventricle with each beat of the heart.

6- Oral Rehydration:

There are many factors that affect fluid intake. They include thirst, hormonal and neurological factors, hypovolemia[10], cellular dehydration, palatability and sensory properties of the beverage including temperature, flavor and carbonation.

Beginning in 1978, the World Health Organization (WHO) and the United Nations Children's Fund (UNICEF) recommended the use of a single formulation (sodium, 90 mEq[11]/L; potassium, 20 mEq/L; chloride, 98 mEq/L; citrate, 10 mmol/L; glucose, 111 mmol/L; and osmolarity, 311 mOsm/L) of oral rehydration solution (ORS) for prevention and treatment of dehydration from diarrheal diseases due to any cause, including cholera, irrespective of patient’s age (Avery & Snyder, 1990). The use of this ORS contributed to the dramatic global reduction in deaths from diarrheal diseases since that time (Victora et al., 2000). The main limitation of this ORS, however, is that it neither reduces stool volume nor diarrhea duration, two factors that are considered important for its acceptance by mothers and health care workers (Mahalanabis et al., 1974). There has also been concern that the solution, which is slightly hyperosmolar relative to plasma, might induce development of hypernatremia or an osmotically driven increase in stool output, especially in infants and young children (Fayad et al., 1992; Rautanen et al., 1993; el-Mougi et al., 1994). For this reason, pediatricians in some developed countries recommended that the sodium content of ORS be reduced from 90 to 60 mEq/L, with a total osmolarity of 250 mOsm/L (ESPGAN[12], 1992).

Recent efforts to improve the efficacy of ORS have focused on solutions with reduced osmolarity (range of sodium, 60-75 mEq/L and range of glucose, 75-90 mmol/L) (Thillainayagan et al., 1998). These solutions generally preserve the 1:1 molar ratio of sodium to glucose that is crucial for efficient cotransport of sodium but present a lower osmolar load to the intestinal tract than the old formula did. Animal and human studies indicate that such solutions might be better designed for optimal water and electrolyte transport into the blood stream. In these intestinal perfusion studies, solutions with reduced osmolarity have been demonstrated to have improved net water absorption and equivalent net sodium absorption compared with standard ORS (Farthing, 1989; Hunt et al., 1989; Rolston et al., 1990; Hunt et al., 1992; Hunt et al., 1994).

7- Hydration, Exercise and Orange Juice:

[10] Hypovolemia: an abnormal decrease in blood volume.
[11] mEq: one-thousandth of a compound's or an element's equivalent weight.
[12] ESPGAN: European Society of Pediatric Gastroenterology and Nutrition

According to the position statement on Exercise and Fluid Replacement by the American College of Sports Medicine (Convertino et al., 1996) it is recommended that individuals consume a nutritionally balanced diet and drink adequate fluids during the 24 hour period before an event, to promote proper hydration before exercise or competition. The addition of proper amounts of carbohydrates and/or electrolytes to a fluid replacement solution is recommended for exercise events of duration greater than one hour since it does not significantly impair water delivered to the body and may enhance performance.

The addition of carbohydrates to a fluid replacement solution can enhance intestinal absorption of water (Schedl et al., 1994). A primary role of ingesting carbohydrates in a fluid replacement beverage is to maintain blood glucose concentration. Solutions containing carbohydrate concentrations greater than 10% will cause a net movement of fluid into the intestinal lumen because of their high osmolality, when such solutions are ingested during exercise. This can result in an effective loss of water from the vascular compartment and can exacerbate the effects of dehydration (Maughan, 1985).

Studies examining the benefits of adding carbohydrates to water during exercise events lasting less than an hour suggest a potential benefit for performance (Ball et al., 1994; Below & Coyle, 1995; Millard-Stafford et al., 1994).

Additional studies have shown that drinking carbohydrate beverages (to provide 30-60 g carbohydrate/h) during vigorous exercise can delay mental fatigue, and improve cognitive function, mood, motor skill performance, and perceived exertion better than drinking the same volume of water (Casa et al., 2005). Furthermore, minimizing dehydration to less than 2% body mass and ingesting carbohydrate improves total physical work capacity, increases time to exhaustion, improves time trial performance, improves power output, and maintains motor skills related to sports performance.

Generally, the inclusion of glucose, sucrose and complex carbohydrates in fluid replacement solutions has equal effectiveness in increasing exogenous carbohydrate oxidation, delaying fatigue, and improving performance. Conversely, fructose should not be the predominant carbohydrate because it is converted slowly to blood glucose and not readily oxidized which does not improve performance. Furthermore, fructose may cause gastrointestinal distress (Convertino et al., 1996).

During research for this paper, the authors had the opportunity to speak via phone conference with Dr. Ann de Wees Allen. Dr. Allen is a board certified doctor of Naturopathy and clinical researcher. She is a personal nutritionist to professional athletes and designed and implemented the Human Maximum Performance Program for professional athletes.

According to Allen, hydration is part of sports performance and is based on liquid that enters the body. “If we are talking about hydration, we are talking about two different things. One is hydration, which is based on the amount of liquid that goes into the human body, but sports performance is based on the configuration of the carbohydrates that go into the human body and their biochemical response in the individual and in each individual sports event”. Allen claims that orange juice is appropriate for that purpose and is what she recommends for her athletes. She further states “orange juice is the preferred hydration fluid as a sports performance drink”.

In a private communication with Leslie Bonci, RD, director of Sports Nutrition at the University of Pittsburgh Medical Center, she stated that “there are numerous studies on the benefit and need for carbohydrate consumption after exercise”. Ms. Bonci identified the following aspects related to carbohydrate consumption after exercise: enhancement of the rate of muscle glycogen repletion, and replacement of fluids lost during exercise. Glucose and sucrose are twice as effective as fructose in restoring muscle glycogen after exercise, and that “because orange juice is sweet, it can increase the drive to drink post exercise more effectively than water”.

There is little physiological basis for the presence of sodium in an oral rehydration solution for enhancing intestinal water absorption as long as sodium is sufficiently available in the gut from a previous meal or in the pancreatic secretions (Schedl et al., 1994). Inclusion of sodium (less than 50 mmol/L) in fluid replacement drinks during exercise has not shown consistent improvements in retention of ingested fluid in the vascular compartment (Convertino et al., 1996). The primary rationale for electrolyte supplementation with fluid replacement drinks is, therefore, to replace electrolytes lost from sweating during exercise greater than 4-5 hours in duration (Armstrong et al., 1993). In most cases, sodium losses which occur from sweating during exercise (less than 4-5 hours) can be replenished by normal dietary intake (National Research Council, 1989).

Interest in the relationship between inflammation and oxidative stress has increased dramatically in recent years. Inflammation and oxidative stress share a common role in the etiology of a variety of chronic diseases; they are linked, during exercise, via muscle metabolism and muscle damage (Peake et al., 2006).

The magnitude of the stress depends on the ability of muscle tissues to detoxify reactive oxygen species (ROS), that is, antioxidant defenses (Sen, 2001). During strenuous exercise, there is a dramatic increase in oxygen uptake in various organs, particularly in the skeleton muscle. Excess ROS release during exercise may have adverse implications on health and performance. Dietary antioxidants may be helpful in reducing excess ROS (Atalay et al., 2006).

An 8 oz glass of orange juice contains less than 10% carbohydrates and the reduced caloric version orange juice beverages contain 5 to 7% carbohydrates. Furthermore, orange juice is composed of 88% water (USDA online database) and contains one part of glucose, two parts of sucrose and only one part of fructose. In addition, orange juice, a flavorful nutrient-dense beverage, is a source of antioxidants like vitamin C and flavonoids that can be utilized as a replacement fluid in preparation for, during and after moderate athletic competitions and exercise.

8- Summary and Conclusions:

Water balance (euhydration) is extremely important in day-to-day life in the maintenance of good health and the prevention of chronic disease. Water is lost from the body in varying amounts via a number of different routes. The total daily water loss is about 2.5 L, but this varies greatly between individuals and depends on environmental conditions.

Dehydration is associated with a number of negative effects on health and well-being. Acute changes in hydration status are commonly designated as dehydration or rehydration.

There is increasing evidence that even mild dehydration, defined as a 1-2% loss in body mass caused by fluid loss affects the onset of various chronic diseases such as kidney stones, urinary tract infection, hypertension, pulmonary disorders and even coronary heart disease.

Some negative subjective symptoms have been also associated with modest levels of dehydration. Self-ratings of alertness and ability to concentrate decline progressively when fluid intake is restricted to induce body mass deficits of even as little as 1-2%. Furthermore, evidence shows that this level of dehydration can significantly impair endurance and sports skills.

Given the increasing awareness of the importance of hydration for health and performance, a significant amount of research has provided new insight into several key aspects of hydration.

Populations at particular risk of dehydration and its sequel include the very young and the elderly. Elderly individuals suffering from chronic physical and/or mental impairment are likely to have low levels of daily water turnover and be at increased risk of hypohydration. The older adult is more likely to have problems maintaining water homeostasis and is more susceptible to dehydration for several reasons. One of the factors for the propensity of dehydration and alteration in water homeostasis in older adults is that the sense or perception of thirst is lessened with age, leading them to not drinking enough to rehydrate themselves.

In spite of great improvements in sanitation and in the availability of rehydration solutions, dehydration resulting from infectious diarrheal disease remains one of the largest single causes of death among young children, being responsible for about 1.5 million deaths annually around the world.

Healthy children may also be at risk of dehydration if there is a sudden increase in water loss for any reason, and physically active children will be at particular risk during periods of warm weather.

Adequate hydration is essential for optimum performance and to ensure that athletes do not incur heat-related illness. Athletes should begin consuming fluids and carbohydrates immediately after exercise to help the body replace fluids lost in sweat and to replenish muscle glycogen stores.

Based on the information gathered for this review, the following points should be emphasized:

- Water balance studies show that daily water needs can vary from 0.6 L for infants to over 6 L for active men. Results indicated that for children and adults, about 80% of the total daily water intake is obtained from beverages and about 20% from food.
- A primary role of ingesting carbohydrates in a fluid replacement beverage is to maintain optimal blood glucose concentration. Athletes should begin consuming fluids and carbohydrates immediately after exercise to help the body replace fluids lost in sweat and to replenish glycogen which is the main source of muscle glucose.
- The addition of carbohydrates to a fluid replacement solution can enhance intestinal absorption of water. The inclusion of glucose, sucrose and complex carbohydrates in fluid replacement solutions has equal effectiveness in increasing exogenous carbohydrate oxidation, delaying fatigue, and improving performance. Because fructose is converted slowly to blood glucose, it should not be the predominant carbohydrate, as it will not improve performance.
- Various studies suggest that orange juice consumption could result in biochemical modification of kidney stone risk factors. Orange juice is a natural rich source of citrate, whose presence in urine is a defense mechanism against calcium stones.
- There is little physiological basis for the presence of sodium in an oral rehydration solution for enhancing intestinal water absorption as long as sodium is sufficiently available in the gut from the previous meal or in the pancreatic secretions. Inclusion of sodium (less than 50 mmol/L) in fluid replacement drinks during exercise has not shown consistent improvements in retention of ingested

fluid in the vascular compartment. In most cases, sodium losses which occur from sweating during exercise (less than 4-5 hours) can be replenished by normal dietary intake.

- During strenuous exercise, there is a dramatic increase in oxygen uptake in various organs, particularly in the skeleton muscle. Excess ROS release during exercise may have adverse implications on health and performance. Dietary antioxidants, such as vitamin C and flavonoids, may be helpful in reducing excess ROS.

Among the readily available beverages to fulfill hydration requirements orange juice is a healthy, flavorful, and nutrient-dense beverage. In addition, Florida orange juice is a convenient, fat and sodium free food composed of about 88% water plus natural vitamins, minerals and flavonoids. Orange juice contains about 10% carbohydrates, which includes one part of glucose, two parts of sucrose and only one part of fructose, and therefore should not be discounted as a fluid replacement beverage before, during and after exercise.

References:

Adolph, E.F. (1947). *Physiology of man in the desert*. New York: Interscience.

Aoi, W., Naito, Y., Yoshikawa, T. (2006). Exercise and functional foods. *Nutr J*. **5**;5:15.

Armstrong, L.E., Curtis, W.C., Hubbard, R.P., Francesconi, R.P., Moore, R., Askew, E.W. (1993). Symptomatic hyponatremia during prolonged exercise in heat. *Med. Sci. Sports Exerc*. **25**:543-549.

Atalay, M., Lappalainen, J., Sen, C.K. (2006). Dietary antioxidants for the athlete. *Curr Sports Med Rep*. **5**:182-186.

Avery, M.E. & Snyder, J.D. (1990). Oral therapy for acute diarrhoea: the underused simple solution. *N Engl J Med*. **323**:891-894.

Ball, T.C., Headley, S., Vanderburg, P. (1994). Carbohydrate-electrolyte replacement improves sprint capacity following 50 minutes of high-intensity cycling. *Med. Sci. Sports Exerc*. **26**:S196.

Ballauff, A., Kersting, M., Manz, F. (1988). Do children have an adequate fluid intake? Water balance studies carried out at home. *Ann Nutr Metab*, **32**:332-339.

Bankir, L., Bardoux, P., Mayaudon, H., Dupuy, O., Bauduceau, B. (2002). Impaired urinary flow rate during the day: a new factor possibly involved in hypertension and in the lack of nocturnal dipping [in French]. *Arch Mal Coeur Vaiss*., **95**:751-754.

Bar-Or, O. (1989). Temperature regulation during exercise in children and adolescents. In: Youth, Exercise and Sport. Ed. CV Gisolfi & DR Lamb, pp 335-367. Indianapolis: Benchmark.

Below, P.R. & Coyle, E.F. (1995). Fluid and carbohydrate ingestion individually benefit intense exercise lasting one hour. *Med. Sci. Sports Exerc*. **27**:200-210.

Blanker, M.H., Bernsen, R.M., Ruud Bosch, J.L., et al. (2002). Normal values and determinants of circadian urine production in older men: a population based study. *J Urol*., **168**(4 part 1):1453-1457.

Carvalho, M., Ferrari, A.C., Renner, L.O., Vieira, M.A., Riella, M.C. (2004). Quantification of the stone clinic effect in patients with nephrolithiasis [in Portuguese]. *Rev Assoc Med Bras*., **50**:79-82.

Casa, D.J., Clarkson, P.M., Roberts, W.O. (2005). American College of Sports Medicine roundtable on hydration and physical activity: consensus statements. *Current Sports Medicine Reports*, **4**:115-127.

Chan, J., Knutsen, S.F., Blix, G.G., Lee, J.W., Fraser, G.E. (2002). Water, other fluids and fatal coronary heart disease. *Am J Epidemiol*., **155**:827-833.

Coe, F.L., Parks, J.H., Webb, D.R. (1992). Stone-forming potential of milk or calcium-fortified orange juice in idiopathic hypercalciuric adults. *Kidney Int.*, **41**:139-142.

Convertino, V.A., Armstrong, L.E., Coyle, E.F., Mack, G.W., Sawka, M.N., Senay, L.C. Jr., Sherman, W. M. (1996). American College of Sports Medicine position stand. Exercise and fluid replacement. *Med. Sci. Sports Exerc*. **28**:i-vii.

Curhan, G.C., Willett, W.C., Speizer, F.E., Stampfer, M.J. (1998). Beverage use and risk for kidney stones in women. *Ann. Intern. Med*., **128**:534-540.

Curhan, G.C., Willett, W.C., Rimm, E.B., Stampfer, M.J. (1996). A prospective study of the intake of vitamins C and B6, and the risk of kidney stones in men. *J Urol*., **155**:1847-51.

Davis, K.M. & Minaker, K.L. (1994). Disorders of fluid balance: Dehydration and hyponatremia. In: Hazard, WR, Bierman, EL, Blass, JP, Ettinger, WH, Halter, JB, editors. New York: McGraw Hill. p 1182-1190.

Dufour, D.R. (2001). *Osmometry: The rational basis for use of a underappreciated diagnostic tool*. New York, NY: Advanced Instruments.

el-Mougi, M., el-Akkad, N., Hendawi, A., et al. (1994). Is a low osmolarity ORS solution more efficacious than standard WHO ORS solution? *J Pediatr Gastroenterol Nutr.* **19**:83-86

Engell, D. & Hirsch, E. (1991). Environmental and sensory modulation of fluid intake in humans. In: Thirst, Physiological and Psycological Aspects. ILSI Human Nutrition Reviews, ed. DJ Ramsey & D. Booth, pp 382-390. London: Springer.

ESPGAN (1992). Report of an ESPGAN working group. Recommendations for composition of oral rehydration solutions for the children of Europe. *J Pediatr Gastroenterol Nutr.* **14**:113-115.

Farthing, M.J. (1989). Disease-related animal models for optimizing oral rehydration solution composition. *Acta Paediatr Scand Suppl.* **364**:23-30

Fayad, I.M., Hirschhorn, N., Abu-Zikry, M., Kamel, M. (1992). Hypernatraemia surveillance during a national diarrhoeal diseases control project in Egypt. *Lancet.* **339**:389-393.

Food and Nutrition Board, Institute of Medicine (2004). Dietary Reference Intakes for Water, Potassium, Sodium, Chloride, and Sulfate. Washington, DC: National Academic Press.

Fusch, C., Gfrorer, W., Koch, C. Thomas, A. Grunert, A., Moeller, H. (1996). Water turnover and body composition during long-term exposure to high altitude (4,900-7,600 m). *J Appl Physiol*., **80**:1118-1125.

Goellner, M.H., Ziegler, E.E., Fomon, S.J. (1981). Urination during the first three years of life. *Nephron.*, **28**:174-178.

Gonzales-Alonso, J., Calbet, J., Nielsen, B. (1998). Muscle blood flow is reduced with dehydration during prolonged exercise in humans. *J. Physiol*. **513**:895-905.

Gopinathan, P.M., Pichan, G., Sharma, V.M. (1988). Role of dehydration in heat stress-induced variations in mental performance. *Arch Environ Health,* **43:**15-17.

Greenleaf, J.E. (1992). Problem: Thrist, drinking behavior, and involuntary dehydration. *Med. Sci. Sports Exerc*. **24**:645-656.

Grossman, S.P. (1990). Thirst and sodium appetite: Physiological basis. New York: Academic Press.

Hattori, M., Azami, Y. (2001). Searching for preventive measures of cardiovascular events in aged Japanese taxi drivers-the daily rhythm of cardiovascular risk factors during a night duty day. *J Hum Ergol* (Tokyo)., **30**:321-326.

Hesse, A. & Siener, R. (1997). Current aspects of epidemiology and nutrition in urinary stone disease. *World J Urol*., **15**:165-171.

Honow, R., Laube, N., Schneider, A., Kessler, T., Hesse, A. (2003). Influence of grapefruit-, orange- and apple-juice consumption on urinary variables and risk of crystallization. *British J. Nutr*. **90**: 295-300.

Hunt, J.B., Elliot, E.J., Farthing, M.J. (1989). Efficacy of a standard United Kingdom oral rehydration solution (ORS) and a hypotonic ORS assessed by human intestinal perfusion. *Aliment Pharmacol Ther*. **3**:565-571

Hunt, J.B., Thillainayagam, A.V., Camaby, S., Fairclough, P.D., Clark, M.L., Farthing, M.J. (1994) Absorption of a hypotonic oral rehydration solution in a human model of cholera. *Gut.* **35**:211-214.

Hunt, J.B., Thillainayagam, A.V., Salim, A.F., Carnaby, S., Elliot, E.J., Farthing, M.J. (1992).Water and solute absorption from a new hypotonic oral rehydration solution: evaluation in human and animal perfusion models. *Gut.* **33**:1652-1659

Kalhoff, H. (2003). Mild dehydration: a risk factor of bronchopulmonary disorders? *Eur J Clin Nutr*. **57**(suppl 2):S81-S87.

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

Mahalanabis, D., Sack, R.B., Jacob, B., Mondal, A., Thomas, J. (1974). Use of an oral glucose-electrolyte solution in the treatment of paediatric cholera: a controlled study. *J Trop Pediatr Environ Child Health.* **20**:82-87.

Manz, F. & Wentz, A. (2003). 24-h hydration status: parameters, epidemiology and recommendations. *Eur J Clin Nutr*. **57** Suppl 2:S10-18.

Manz, F. & Wentz, A. (2005). The importance of good hydration for the prevention of chronic diseases. *Nutr Rev*, **63**: S2-S5.

Maughan, R.J. (1985). Thermoregulation and fluid balance in marathon competition at low ambient temperature. *Int J Sports Med*, **6**:15-19.

Maughan, R.J. (2003) Impact of mild dehydration on wellness and on exercise performance. *Eur J Clin Nutr*. **57** Suppl 2:S19-23.

Mazzola, B.L., von Vigier, R.O., Marchand, S., Tonz, M., Bianchetti, M.G. (2003). Behavioral and functional abnormalities linked with recurrent urinary tract infections in girls. *J Nephrol*., **16**:133-138.

Millard-Stafford, M., Rosskopf, L.B., Snow, T.K., Hinson, B.T. (1994). Pre-exercise carbohydrate-electrolyte ingestion improves one-hour running performance in the heat. *Med. Sci. Sports Exerc*. **26**:S196.

Moloney, E., O'Sullivan, S., Hogan, T., Poulter, L.W., Burke, C.M. (2002) Airway dehydration: a therapeutic target in asthma? *Chest*., **121**:1806-1811.

Montain, S.J. & Coyle, E.F. (1992). Influence of graded dehydration on hyperthermia and cardiovascular drift during exercise. *J. Appl. Physiol*. **73**: 1340-1350.

Moran, D., Heled, Y., Margaliot, M. et al. (2004). Hydration status measurement by radio frequency absorptiometry in young athletes - a new method and preliminary results. *Physiol Meas*. **25**:51-59.

Nadel, E.R. (1989). Circulatory and thermal regulations during exercise. *Fed. Proc*. **39**:1491-1498.

National Research Council. (1989). Recommended Dietary Allowances, 10th Ed. Washington, DC: National Academy Press, pp.250-255.

Nijssen-Jordan, C. (1997). Can oral rehydration solution be safely flavored at home? *Pediatric Emergency Care* **13**: 374-375.

Odvina, C.V. (2006). Comparative value of orange juice versus lemonade in reducing stone-forming risk. *Clin J Am Soc Nephrol*, **1**:1269-1274.

Peake, J.M., Suzuki, K., Coombes, J.S. (2006). The influence of antioxidant supplementation on markers of inflammation and the relationship to oxidative stress after exercise. *J Nutr Biochem*. **5 (in print).**

Popkin, B.M., Armstrong, L.E., Bray, G.M., Caballero, B., Frei, B., Willett, W.C. (2006). A new proposed guidance system for beverage consumption in the United States. *Am J Clin Nutr*. **83**:529-542.

Porth, C.M. & Erickson, M. (1992). Physiology of thirst and drinking: Implications for nursing practice. *Heart Lung*, **21**: 273-282.

Raman, A., Schoeller, D., Subar, A., et al. (2004). Water turnover in 458 American adults 40 – 79 yr of age. *Am J Physiol Renal Physiol*, **286**:F394-F401.

Rautanen, T., el-Radhi, S., Vesikari, T. (1993). Clinical experience with a hypotonic oral rehydration solution in acute diarrhoea. *Acta Paediatr.* **82**:52-54.

Report of an ESPGAN Working Group. (1992). Recommendations for composition of oral rehydration solutions for the children of Europe. *J Pediatr Gastroenterol Nutr.* **14**:113-115.

Ribeiro, G.A., Rodrigues, L.O., Moreira, M.C., Silami-Garcia, E., Pascoa, M.R., Camargos, F.F. (2004). Thermoregulation in hypertensive men exercising in the heat with water ingestion. *Braz. J. Med. Biol. Res*. **37**:409-417.

Rolston, D.D., Zinzuvadia, S.N., Mathan, V.I. (1990). Evaluation of the efficacy of oral rehydration solutions using human whole gut perfusion. *Gut.* **31**:1115-1119.

Rothstein, A., Adolph, E.F., Wills, J.H. (1947). Voluntary dehydration. In *Physiology of Man in the Desert*, E.F. Adolph and Associates, eds, pp. 254-270. New York: Intersciences Publishers.

Ruby, B.C., Shriver, T.C., Zderic, T.W., Sharkey, B.J., Burks, C., Tysk, S. (2002). Total energy expenditude during arduous wildfire suppression. *Med Sci Sports Exerc*., **34**:1048-1054.

Sawka, M.N., Pandolf, K.B. (1990). Effects of body water loss on physiological function and exercise performance. In *Perspectives in Exercise Science and Sports Medicine*. Vol. 3, ed. CV Gisolfi & DR Lamb, pp1-38. Misc: Indianapolis: Benchmark Press.

Sen, C.K. (2001). Antioxidants in exercise nutrition. *Sports Med*. **31**:891-908.

Schedl, H.P., Maughan, R.J., Gisolfi, C.V. (1994). Intestinal absorption during rest and exercise: implications for formulating an oral rehydration solution (ORS). *Med. Sci. Sports Exerc*. **26**:267-280.

Sharma, V.M., Sridharan, K., Pichan, G., Panwar, M.R. (1986). Influence of heat stress-induced dehydration on mental functions. *Ergonomics*, **29**:791-799.

Sheehy, C.M., Perry, P.A., Cromwell, S.L. (1999). Dehydration: biological considerations, age-related changes, and risk factors in older adults. *Biological Research for Nursing*, **1**:30-37.

Shirreffs, S.M. & Maughan, R.J. (1998). Urine osmolality and conductivity as indices of hydration in athletes in the heat. *Med. Sci. Sports Exerc*. **30**:1598-1602.

Stauffer, C.M., van der Weg, B., Donadini, R., Ramelli, G.P., Marchand, S., Bianchetti, M.G. (2004). Family history and behavioral abnormalities in girls with recurrent urinary tract infections: a controlled study. *J Urol*., **171**:1663-1665.

Suhr, J.A., Hall, J., Patterson, S.M., Niinisto, R.T. (2004). The relation of hydration status to cognitive performance in healthy older adults. *Intern J Psychophysiology*, **53**:121-125.

Thillainayagam, A.V., Hunt, J.B., Farthing, M.J. (1998). Enhancing clinical efficacy of oral rehydration therapy: is low osmolarity the key? *Gastroenterology.* **114**:197-210.

Victora, C.G., Bryce, J., Fontaine, O., Monasch, R. (2000). Reducing deaths from diarrhoea through oral rehydration therapy. *Bull World Health Organ.* **78**:1246-1255.

Wabner, C.L. & Pak, C.Y. (1993). Effect of orange juice consumption on urinary stone risk factors. *J Urol.* **149**:1405-1408.

Welch, B., Buskirk, E., Iampietro, P. (1958). Relation of climate and temperature to food and water intake in man. *Metabolism*, **7**:141-148.

Wilde, M.H., Carrigan, M.J. (2003). A chart audit of factors related to urine flow and urine tract infection. *J Adv Nurs*., **43**:254-262.

Wilson, M-MG., Morley, J.E. (2003). Impaired cognitive function and mental performance in mild dehydration. *Eur J Clin Nutr*. **57** Suppl 2:S24-29.

WHO (2002). New formula for oral rehydration salts will save millions of lives. WHO press release, 8 May: www.who.int/.