

Review Article

Proper hydration is central to the health and well-being of children

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Introduction

On an average, 50-70% of the body consists of water distributed in the intracellular and extracellular compartments¹. Water is essential for thermoregulation, as well as for all metabolic functions of the body². It is continuously lost from the body via urine, faeces, breath and skin. This water loss should be replaced continuously by water, fluids and diet in order to maintain water balance¹. Though adults can maintain water balance efficiently, young infants and children are at a higher risk of dehydration³. Even mild dehydration can produce multiple negative impacts on the health and well-being of infants and young children³. This review discusses the central role of water in the body, water recommendations, effects of dehydration in children, assessment of hydration status in children and summarises the findings of available research studies conducted on the hydration status of children and their impact.

Method

A literature search was conducted using Google Scholar, PubMed, Medline, and Cochrane library databases. 'Hydration', 'dehydration', 'hydration of children', 'water requirement', 'impacts of hydration', were the search terms used. The literature search was limited to articles published in English.

Results

Water and life

Earth is known as the 'Water Planet' as about 75% of the earth comprises water⁴. Approximately 70%

of the human body consists of water⁴. Water is the fundamental solvent which is essential for nearly all biochemical reactions that take place in the body, including cellular respiration⁵. Water aids in the proper electrolyte balance in the body and thereby helps to maintain optimal functioning of vital organs such as the brain⁵. Being the main part of blood, water plays a key role in maintaining a healthy cardiovascular system⁵. Without water there is no existence or life.

Water recommendations

Gender and age-specific daily water intake recommendations have been published by the Institute of Medicine (IOM), USA⁶. According to IOM recommendations, adequate total water intake is 0.7 L/day for infants aged 0-6 months and 0.8 L/day for infants aged 7-12 months. Recommended water intake for 1-3-year-old children and 4-8-year-old children are 1.3 L/day and 1.7 L/day, respectively. Boys and girls aged 9-13 years should ingest 2.4 L/day and 2.1 L/day respectively. Boys and girls above 14 years old should ingest 3.3 L/day and 2.3 L/day respectively. Good hydration plays a pivotal role in good health and well-being of individuals of all ages⁷.

Dehydration

Dehydration is defined as a rapid loss of over 3% of body weight in relation to water and electrolyte disturbance due to water or sodium depletion⁸. Dehydration is classified as isotonic, hypertonic or hypotonic⁸. Isotonic dehydration is a balanced depletion of water and sodium which results in extracellular fluid (ECF) loss⁸. Hypertonic dehydration is depletion of total body water content due to reduced water intake, pathologic fluid losses or both. Here, due to the resulting hypernatraemia in the ECF, water is drawn from the intracellular fluid (ICF)⁸. Hypotonic dehydration occurs due to depletion of sodium and water where sodium loss predominates, creating an ECF loss⁸. Dehydration is associated with morbidity and mortality in individuals of all ages⁹.

Symptoms of dehydration vary, based on the amount of water loss. When water loss is about 1% of body weight, increased thirst and impairment of thermoregulation occur¹⁰. Thirst is increased at 2% of water loss; at 3% water loss, symptoms such as

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dry mouth, vague discomfort and loss of appetite are reported. Impairment of 20-30% work capacity is seen at 4% water loss and at 5% water loss, headache, difficulty in concentration and sleepiness are reported. At 6% tingling and numbness of extremities are reported and at 7% of water loss collapse occurs and death is reported at 10% dehydration¹⁰.

Dehydration consequences in children

Infants and young children possess higher metabolic needs and higher metabolic rates³. Their insensible water loss is also higher due to higher body surface area to volume ratio³. Therefore, they are more susceptible to dehydration. Dehydration is reported as a major cause of morbidity and mortality in infants and young children worldwide¹¹. Maintenance of optimal hydration is crucial for infants and children due to many physiological and behavioural motives².

Assessment of hydration status

Change of body weight, bioelectrical impedance, urine colour, urine osmolality, urine specific gravity, plasma osmolality and saliva osmolality are among the techniques used to assess the hydration status¹². Measurement of body weight change is the simplest method to assess acute changes in body water. This can be performed quickly, easily, and does not require technical expertise. However, changes of body composition not related to hydration status makes this method unreliable for long duration studies. As body weight is affected by fluid intake, food ingestion, faecal losses and urine production etc., body weight change does not reflect hydration status over hours. Therefore, measurement of body weight change is not appropriate for assessing hydration status in free-living conditions¹².

Isotope dilution is an accurate method to measure total body water. Here, a precise trace amount of an isotope (commonly deuterium) is administered orally or intravenously. The tracer is distributed all over the body fluid compartments. After reaching equilibrium, tracer concentration is measured in plasma, urine or saliva. However, isotope dilution methods are very costly and need high technical expertise. Bioelectrical Impedance Analysis (BIA) is a technique to measure body water based on the electrical properties of tissues. Depending on water and electrolyte content, different tissues conduct electrical current differently and considering this property, sex and age specific equations are developed to link body resistance to the electrical current of total body water, extra cellular water and intracellular water¹⁴. BIA techniques provide rapid feedback, are non-invasive, inexpensive and easy to perform. However, their sensitivities and reproducibility have been questioned as many factors affect BIA measurements.

Historically, plasma osmolality has been considered a standard marker for assessing the hydration status¹⁴. Osmolality could be determined using a freezing-point depression osmometer or a vapour pressure-depression osmometer. Though this technique is inexpensive, it is invasive and not suitable for children. Further, relevance of plasma osmolality is a matter of context. For example, in acute dehydration such as during physical exercise, plasma osmolality is changed, yet in chronic dehydration, plasma osmolality could be preserved through brain regulation and kidney adaptation¹⁵.

Urinary indices are widely used for assessing the hydration status. There are three main urinary markers, namely, urine colour, urine osmolality and urine specific gravity. Concentration of osmotic solutes in urine denotes urine osmolality and it is measured by using freezing-point or vapour pressure-depression osmometers. Urine osmolality is governed by the amounts of solutes and the volume of water. Most abundant solutes in water are sodium, potassium and urea and their concentrations depend on the diet. Dehydration produces highly concentrated small volumes of urine with a higher osmolality. Under proper hydration conditions, large volumes of urine are produced with low osmolality. Urine osmolality reflects the capacity of the kidneys to respond to variations in body water balance and ranges from 50 to 1400 mOsm/kg. In some pathological conditions like diabetes insipidus and chronic kidney disease, renal functions and capacities are compromised, and in such situations, urinary indices should not be used⁸. Urine osmolality is adequately sensitive to catch minor changes in hydration status. Urine osmolality is reported to represent dehydration more accurately than blood indices¹⁶. It is non-invasive and inexpensive.

Urine specific gravity is the weight of urine divided by the weight of an equal volume of distilled water. Specific gravity of plain water is 1.000. In normal urine specific gravity usually ranges from 1.013 to 1.029. Dehydration has been defined by a urine specific gravity above 1.020-1.025. Urine specific gravity test strips are available but the refractometer is the 'gold standard' for measuring urine specific gravity. Studies have reported that urine osmolality and urine specific gravity are powerfully correlated and consistent¹⁶.

The third common urinary marker used for assessing hydration status is urine colour. A urine colour chart has been developed to measure urine concentration of healthy humans¹⁷. This chart contains a standardized colour scale ranging from 1 (pale yellow, corresponding to dilute urine) to 8 (dark brown, corresponding to concentrated urine). Cut-off value between euhydration and dehydration has

been set as 4. Urine colour is a cheap non-invasive tool which does not require technical expertise. Further, it provides immediate results. This method is reported to have the best specificity (97%) among all urinary markers¹⁷. However, the urine colour chart lacks sensitivity and could be disturbed by dietary factors, illness and medications. A linear relationship has been established between urine colour, osmolality and specific gravity suggesting that all of them are suitable for assessing the hydration status.

Research related to hydration of children

Suh H, *et al*¹⁸ published a review of the water intake practices and hydration status of children. There were 32 observational studies in this review representing a total of 36,813 children. The review compared the total water/fluid intake and water intake recommendations with the underhydration cut-off of urine osmolality $>800\text{mOsm/kg}$, of children living in 25 countries. Of 32 studies, only 11 reported both the water intake and hydration status of children. Twelve studies reported average water/fluid intake below the guidelines, and 4 studies reported underhydration based on urine osmolality ($>800\text{mOsm/kg}$). Nineteen countries compared water/fluid intake with the guidelines, and reported that $60 \pm 24\%$ children (10-98%) failed to meet the guideline. This suggests that children are not ingesting enough water/fluid and are not adequately hydrated.

Zaghloul G, *et al*¹⁹ evaluated the morning hydration status of 519 school children 9-11 years old in Egypt. The study collected information about the children's breakfast and their urine osmolality was analysed. The average urine osmolality of children was 814mOsm/kg ; in 57% children, it was $>800\text{mOsm/kg}$ and in 24.7% it was $>1000\text{mOsm/kg}$. A total water intake below 400mL was associated with a greater risk of dehydration. This study concluded that most Egyptian school children arrived at school with a hydration deficit.

Barker M, *et al*²⁰ evaluated the morning hydration status of 452 British primary school children, aged 9-11 years, in South Yorkshire, related to breakfast water intake. Children's urinary osmolality was measured and data on dietary intake and fluid consumption were collected. There was a mild hydration deficit in 60% children with urinary osmolality above 800mOsm/kg . There was a high prevalence of elevated urinary osmolality in boys compared to girls (68.4% vs 53.5%). In 18.6% children urinary osmolality was over 1000mOsm/kg .

Bonnet F, *et al*²¹ assessed the morning hydration status in 529 French schoolchildren aged 9-11 years. Urine samples of the children were collected in the

morning to measure urine osmolality and their food and fluid intake data were collected to calculate the nutritional composition. More than one third of children had urine osmolalities ranging from 801-1,000mOsm/kg. About 22.7% children had urine osmolality over 1,000mOsm/kg. It was more significant in boys than girls. Majority (73.5%) of children had consumed less than 400 mL at breakfast. Total water intake at breakfast was significantly and inversely related to high urine osmolality. Over two thirds of children in the sample had a hydration deficit.

Iglesia-Altaba I, *et al*²² studied the patterns of fluid consumption in 146 children and adolescents by a cross-sectional study in Spain, and compared them with adequate water intake recommendations by the European Food Safety Agency (EFSA). This study assessed total fluid intake from all sources by means of a validated liquid intake 7-day record. Results indicated that 73% children and 72% adolescents had not met EFSA recommendations for fluid intake. Furthermore, 40% children and 50% adolescents were consuming sugar-sweetened beverages (SSB) at least once a day. Study concluded that the drinking habits of Spanish young populations were far removed from current recommendations and that their SSB consumption was higher.

Laksmi PW, *et al*²³ reported the daily total fluid intake (TFI) with the types of fluids in Indonesia and compared TFI with the fluid intake recommendations established by the Ministry of Health, Republic of Indonesia. They collected data in 32 cities over nine Indonesian regions. Their sample comprised 388 children 4-9 years old, 478 adolescents 10-17 years old and adults. They used a validated fluid intake 7-day record for data collection. According to their results, 67% participants met adequate intake (AI) of water from fluids; 78% children and 80% adolescents met AI. Though drinking water was the chief contributor to TFI in every age group, sugar-sweetened drinks were consumed by 62% children and 72% adolescents. Furthermore, an SSB intake ≥ 1 serving/day was observed in 24% children and 41% adolescents.

The relationship between hydration and cognitive performance is an emerging area of research. A study conducted in USA investigated the association between total water intake and cognitive control among pre-pubertal children. In this study, to assess cognitive control and ability to battle distractions and maintain focus, children aged 8-9-years completed a modified flanker task. Results of the study indicated an association between water intake and cognitive control by means of a task that modulates inhibition. Excessive intake of water

correlated with higher ability to maintain task performance once inhibitory demands were increased²⁴. Though the mechanism by which fluid intake arbitrates cognition and brain health is unclear in humans, animal studies have provided evidence for dehydration-induced curtailment in neuronal cell proliferation and neuronal cell shrinkage due to water depletion from cells²⁵. Further, dehydration is known to elevate circulatory stress hormone levels i.e., cortisol which are related to decrements in cognitive function²⁶.

Bar-David Y, *et al*²⁷ conducted a study to assess the relationship between cognitive test scores and the state of hydration in 58 elementary school students in grade 6, aged 10.1-12.4 years. Urine samples of the children were collected in the morning and noon to measure urine osmolality and five cognitive tests (number addition, hidden figures, auditory number span, making groups and verbal analogies) were performed in the morning and at noon-time. Of the sample, 32 students were dehydrated (urine osmolality >800mOsm/kg) in the morning. Results indicated an overall significant positive trend in four of the five tests in the hydrated group suggesting that dehydration is a common issue in school-aged children which adversely affects their cognitive functions.

Amaerjiang N, *et al*²⁸ conducted a longitudinal study in China to assess the variations in hydration status and renal impairment, among 1885 children (mean age 7.7 years). They used urine specific gravity to assess the dehydration status, and the levels of β -2-microglobulin (β 2-MG) and microalbumin (MA) to evaluate the impairment of renal functions. Study reported that prevalence of dehydration among children was 61.9%, and that it was significantly higher in boys (64.3%). Study documented tendencies for the change of renal indicators over time along with different hydration statuses. A new indicator ratio, β 2-MG/MA, has validated the consistent trends of renal function impairment (especially related to tubular stress/damage), in dehydrated children. Renal impairment trends have been shown to worsen as a function of school days of the week. Further, dehydration status was shown to intensify the renal impairment in childhood during the school weekdays.

Summary and conclusions

Water is the basis of life. It is essential for metabolism, transport of substances across the body, thermoregulation, cellular homeostasis and proper circulatory as well as cognitive functions. Optimal water intake and appropriate hydration status positively affect multiple cardinal aspects of human physiology. Though water is cheap, the value added by water to life and good health is expensive. However, this aspect has not been addressed well up

to date. Though there is growing interest in the area of hydration over the last couple of years, research has not focused adequately on the hydration status and its impacts, especially in children. Children are at a great risk of dehydration. Available limited literature provides concrete evidence that the majority of children are poorly hydrated. It is of paramount importance to better understand the barriers in children for drinking water, and pay attention to encourage and promote their water intake through multi-component interventions, combining educational, behavioural and environmental approaches, in order to ensure adequate hydration, optimal cognition, as well as proper cardiovascular and renal functions in children.

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