Hydration in Children: What Do We Know and Why Does it Matter?

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Keywords

Hydration · Water intake · Children · School · Barriers · Interventions · Behavior change

Abstract

In children, maintaining adequate fluid intake and hydration is important for physiological reasons and for the adoption of healthy, sustainable drinking habits. In the Liq.In⁷ cross-sectional surveys involving 6,469 children (4–17 years) from 13 countries, 60% of children did not meet the European Food Safety Authority (EFSA) adequate intake for water from fluids. Beyond fluid quantity, the quality of what children drink is important for health. In these surveys, the contribution of sugar-sweetened beverages and fruit juices to total fluid intake (TFI) in children exceeded that of water in 6 out of 13 countries. To assess the adequacy of children's fluid intake, urinary biomarkers of hydration such as urine osmolality, urine specific gravity, and urine color may be used. To date, while there are no widely accepted specific threshold values for urine concentration to define adequate hydration in children, the available literature suggests that many children

have highly concentrated urine, indicating insufficient fluid intake. This is worrisome since studies have demonstrated a relationship between low fluid intake or insufficient hydration and cognitive performance in children. Furthermore, results of the Liq.In⁷ surveys showed that at school – where children spend a significant amount of time and require optimal cognitive performance – children drink only 14% of their TFI. Consequently, it is pertinent to better understand the barriers to drinking water at school and encourage the promotion of water intake through multicomponent interventions that combine educational, environmental, and behavioral aspects to support adequate hydration as well as optimal cognition in children.

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Published by S. Karger AG, Basel

Introduction

In recent decades, research demonstrating an association between water intake and/or hydration and health has raised interest for this topic within the scientific community and in the eyes of public health professionals.

While there is benefit in improving eating and drinking behaviors in adulthood, concentrating on the acquisition of healthy consumption habits in children may prove to be a more sustainable and successful strategy for the prevention of health risks. This article aims to provide an overview of research on water, fluid intake, and hydration in children and their importance for health both from a physiological and behavioral viewpoint, as well as to provide perspective of what may be needed to create and maintain a water-friendly environment at different levels, at the levels of family and school in particular.

Water Balance in Children

In children, maintaining adequate fluid intake and optimal hydration is essential for physiological and behavioral reasons. Water is the most abundant component of the human body. In newborns, who have developed in an aqueous milieu, body water content at birth is approximately 75% of body mass [1]. This is much higher than that of adults for whom water represents 50–60% of body mass. The relative water content of infants decreases rapidly throughout the first year of life to 60% and remains relatively stable throughout childhood until adolescence, after which changes in body composition and hormonal balance result in reduced water content, particularly in young women [2–4]. Physiologically, water supports many functions essential in daily life, such as thermoregulation and waste elimination; it also serves as a carrier and a solvent for numerous metabolic reactions. In children, physiological specificities of water balance, such as the progressive maturation of kidney function by around the age of 2, as well as a higher body surface-to-body mass ratio which translates into higher insensible water loss through the skin, explain in part why children have higher water requirements relative to their body mass when compared with adults [4, 5]. Voiding volume and frequency also reach their full maturity by adolescence only [6].

Water Intake in Early Childhood: A Driver of Sustainable Healthy Habits?

Beyond physiological differences, water is also an essential component of the adoption of healthy sustainable drinking habits in children. Acquiring healthy drinking habits is important from infancy because many dietary behaviors acquired during childhood persist into adult-

hood. For example, Fiorito et al. [7] demonstrated that consumption of sugar-sweetened beverages (SSB) at age 5 predicted the consumption of SSB at age 13. Similar associations were obtained in different countries and age categories [8, 9]. However, the association between early childhood and later life intake has never been demonstrated for drinking water, due to the scarcity of longitudinal studies assessing water intake. But if indeed drinking habits (i.e., plain water intake in particular) were sustained throughout life, children who drink little water would become adults who drink little water with potential consequences for kidney [10] and metabolic health [11, 12] as well as cognitive and mood impairments [13, 14]. During early childhood, the acquisition of eating and drinking behavior is mainly driven by adults since children depend upon them for the provision of food and beverages, and adults serve as role models which children copy and acquire habits from. Indeed, numerous studies support an association between parent and child food and beverage intake, including SSB in particular [15–17]. While there is no peer-reviewed published research on the association between parents' and children's water intake, results from a survey commissioned by the Natural Hydration Council, involving 1,000 parents from across the United Kingdom and one of their children, aged 4–8 years old, showed that children whose parents were drinking plain water often were more likely to drink plain water themselves; this demonstrated that parents can positively influence the drinking habits of their children [18]. In addition to parental influence on eating and drinking habits during childhood, school environment, rules, and policies also play a crucial role in the acquisition of healthy consumption behaviors. Regarding water intake, observational studies have shown that consumption of water in schools where water intake is encouraged (i.e., by ensuring water access, providing appropriate water fountains and toilet facilities, and education about the importance of hydration), is greater than in schools that do not have supporting rules and infrastructure in place [19, 20].

Water and Fluid Intake Habits of Children

To better understand drinking behaviors in children, studies have attempted to assess the quantity and quality of their fluid intake. However, assessing fluid intake in children involves multiple challenges (e.g., multiplicity of caregivers and/or locations throughout the day, bias in parental diet records, on-going cognitive capacity development, limited literacy skills, difficulties in estimating

portion sizes, differences in child portion sizes compared with those of adults, and a tendency not to finish servings) [21]. Additionally, plain water intake is often overlooked in clinical and observational studies focusing on obesity because water contains no calories. Consequently, in a systematic review of studies reporting fluid intake published in 2014, Ozen et al. [22] found that of the 34 publications reporting fluid intake in children, less than half included any measure of plain water intake. In practice, the omission of water means that in the majority of studies investigating the associations between childhood nutrition and health outcomes, water is absent.

Recently, fluid intake data that include drinking water have become available with the publication of the Liq.In⁷ survey results. The harmonized Liq.In⁷ cross-sectional surveys, collected with 7-day fluid specific records, encompass data on the consumption of all types of beverages including plain water for 6,469 children (4–17 years) from 13 countries [23]. A first analysis of the data highlighted large discrepancies in total fluid intake (TFI; sum of all beverages including plain water) both between countries and within countries [24]. As an example, the mean TFI of 4–9-year-old children in Indonesia was 1.9 ± 0.8 L, twice the intake of Belgian children: 0.8 ± 0.4 L. In Brazil, there was a 6-fold difference of TFI between the 5th and 95th percentile. This suggests that, in order to identify individuals who have increased fluid intake-associated health risks, data should be analyzed at the individual level rather than at the mean population level. Therefore, comparing individual children's TFI to the daily adequate intake for water (i.e., from recommendations provided by health authorities such as the European Food Safety Authority, EFSA), the results demonstrated that 61% of children in the Liq.In⁷ surveys did not meet the adequate intake for water from fluids derived from EFSA [24]. Focusing on the quality of fluid intake, these surveys demonstrated that the contribution of SSB and fruit juices to TFI in children exceeded that of water in 6 out of 13 countries [25]. Moreover, 55% of children and adolescents in the sample consumed more than 1 serving of SSB daily, while up to 21% did not drink water on a daily basis in some countries (unpublished data). This raises concern since the negative consequences of SSB consumption on children's health have been highlighted in numerous studies demonstrating that children who consume one or more SSB serving per week have a 50–80% increased risk of dental caries, overweight and obesity, and metabolic syndrome compared with non- or sporadic consumers of SSB [26–33].

Hydration Assessment of Children

As in adults, markers of urine concentration such as osmolality, specific gravity, and color may be used for day-to-day hydration assessment of children [34, 35]. Urine color, in particular, may be used for self-assessment of hydration since it can reliably be self-assessed by children above 8 years of age [36]. To date, however, there are no widely accepted specific threshold values for urine concentration to define adequate hydration in children. Previous studies have utilized cutoff values of 500, 800, and 830 mOsmol/kg, referring to different terminologies such as mild dehydration, euhydration, appropriate hydration, hypohydration, and underhydration, without any evidence for health benefit or risk [37–40]. This is mainly due to the scarcity of studies demonstrating an association between a quantified fluid intake or urine volume or concentration and a health benefit or risk in children. In fact, very few studies have investigated the effect of hydration on health outcomes in children. Preliminary evidence demonstrates a link between hydration and physical performance in children: improving hydration by providing education regarding the importance of hydration, a urine color scale [41] to assess the hydration before and after exercise, and by improving water access resulted in increased performance during an endurance run by athletic children [42]. This is relevant since some studies suggest that a majority of child athletes may be insufficiently hydrated before they start exercising [43, 44]. While there are limited data concerning preexercise hydration status of children from the general population, research suggests that many of them have elevated urine concentration on a given “normal” day across various countries [45–49]. Hydration has also been linked to cognitive performance in children in a number of studies [38, 39, 50, 51]. In a cross-sectional study, Bar-David et al. [38] demonstrated that insufficient hydration, indicated by elevated urinary markers of hydration, was associated with poorer short-term memory performance in children. Although limited, a handful of interventions have also indicated that providing children with water results in improved cognitive performance [39, 50, 51].

Water and Hydration at School: Running on Empty?

In this context, understanding the drinking behaviors of children during school, where optimal cognitive performance is essential, seems relevant. A more detailed investigation of fluid intake within 6 countries of the Liq.In⁷

Fig. 1. Proportion of daily TFI in children by location in the Liq.In⁷ surveys. Age of the children: 4–17 years old. Sample size for Mexico: *n* = 669; Brazil: *n* = 340; Argentina: *n* = 392; Uruguay: *n* = 265; China: *n* = 649; Indonesia: *n* = 866. Adapted from Morin et al., 2018 *Eur J Nutr* 57(Suppl 3):101–12.

surveys showed that children only consume 14% of their TFI at school, despite spending approximately half of their waking hours at school (Fig. 1) [52]. This is further confirmed by the results of clinical studies demonstrating that many children have highly concentrated urine before or during school [46, 48, 49, 53, 54] (Table 1), suggesting that a large proportion of children arrive at school already in a state of water conservation, and continue not to drink adequately during the school day. Understanding the barriers that prevent children from drinking at school is essential to promote water intake at school through successful behavior change interventions. Earlier research in this area highlighted barriers in teachers, including poor teacher knowledge of the effect of hydration on cognition, and a fear of disruption to class due to increased need to urinate [55]. Consequently, many teachers limit toilet use to specific times, which may be perceived by children as too short to use the toilet facilities [56]. Other barriers to toilet use reported by children include toilet dirtiness, unpleasant smell, and the fear of bullying [57–60]. As a result, studies highlight that up to 1 out of 4 children report not using the toilets at school to urinate, and 4 out of 5 children not using toilets to defecate [58–60]. Preliminary evidence from France also suggests that this may have consequences on a child's quality of life and ability to focus since 30% of children reported having trouble concentrating because of abdominal pain as a result of not using toilets [59].

Finally, results from the Liq.In⁷ surveys demonstrate that many schools simply do not provide access to water for children [52]. This has obvious consequences on drinking behavior as demonstrated by a study of 6 schools in the United Kingdom in which children with limited access to water at school were almost twice as likely to drink below a recommended fluid quantity during school time (calculated from EFSA recommendations) as compared to children with free water access [20], confirming that access to water is a primary driver of water intake at school. In another study from Belgium, comparing hydration in children from 17 primary schools with different school policies on water, children's hydration, assessed by urine osmolality, was better in schools which supported water availability, toilet and hydration-related education, good toilet infrastructure, a formal agreement on drinking and toilet visits, as well as participation of parents and children during the development of policies [19].

Finally, in a toolkit analyzing data from 18 interventional studies, the European Commission joint research center focused on successful measures to promote water consumption and reduce SSB intake in schools. While success was relatively low globally across the studies, multicomponent interventions (i.e., education, changes in the drinking environment including water fountains and/or restricted access to SSB, and a behavioral component involving the family) were found to be

Table 1. Mean osmolality measured in urine samples collected before or during school in clinical studies

Reference	Year	Country	Number (male/female)	Age, years	School collection time	Urine osmolality, mOsmol/kg, mean (SD)	Range of urine osmolality values	Percentage of children with urine osmolality <500 (a) or <600 (b) mOsmol/kg	Percentage of children with urine osmolality >800 mOsmol/kg	Percentage of children with urine osmolality >1,000 mOsmol/kg
Michels et al. [46]	2015	Belgium	371 (176/195)	7–13	School start (around 10 a.m.)	888 (192)	94–1,262	8.9 (b)	76	
Michels et al. [46]	2015	Belgium	371 (176/195)	7–13	Pooling of all samples collected during school time	767 (310)	91–1,291	34 (b)	53.6	
Gouda et al. [48]	2015	Egypt	519 (260/259)	9–11	30 min after breakfast (37%) or fasting sample upon awakening if no breakfast (63%)	814 (250)	122–1,525		57	24.7
Bonnet et al. [47]	2012	France	529 (269/260)	9–11	30 min after breakfast or second void of the morning if no breakfast	823 (227)			62.2	22.7
Robers et al. [65]	1996	Germany	231 (231/0)	3–18	24 h	801				
Robers et al. [65]	1996	Germany	238 (0/238)	3–18	24 h	729				
Soto-Mendez et al. [66]	2015	Guatemala	78	2–7	24 h started from 7 to 8 a.m.	430 (median) 407–491 (95% CI)	115–1,102			
Philip et al. [67]	1993	Israel	200 (125/75)	2–6	Noon time	791 (201)			60.5	7
Bar-David et al. [54]	2009	Israel	428	8–10	Noon time	862 (211)		6.8 (a)	67.5	25
Bar-David et al. [38]	2005	Israel	51 (19/32)	10.1–12.4	Morning (8 a.m.)	856 (232)			62.7	25
Bar-David et al. [38]	2005	Israel	51 (19/32)	10.1–12.4	Noon (1 p.m.)	813 (294)			62.7	25
Kawauchi et al. [49]	1996	Japan	1,453	3–12	First morning urine sample immediately after waking	900 (233)				
Skinner et al. [68]	1996	United Kingdom	322 (170/162)	3–18	Early morning urine sample	845 (median)	275–1,344	17.8 (M) (b) 25.2 (F) (b)		
Stookey et al. [53]	2012	United States	337 (172/165)	9–11	8.30–9.30 a.m.	827 (250)	99–1,372		63	25
Stookey et al. [53]	2012	United States	211 (116/95)	9–11	8.30–9.30 a.m.	853 (219)	186–1,259		66	27

most successful. Indeed, while education and access to water are at the base of hydration, influences from peers, especially in teenagers, may be a key component of changing behaviors. Recent studies have shown that it is possible to increase water and decrease SSB intake in children through a social network-based intervention using the most influential children to promote water consumption [61, 62]. Testing different ways to nudge, enable, or motivate water intake by children

may also be useful in identifying the most successful components for initiating and maintaining behavior change in the future [63, 64].

To support adequate intake and optimal hydration in children during school, it therefore seems relevant to: (1) identify barriers to drinking water in schools at the local level, (2) promote and facilitate access to free water access at school and during class as well as improve toilet facilities, (3) educate children, teachers and parents about the

Fig. 2. Identified barriers of water intake in children and possible levers of action to overcome them at school.

importance of water intake and hydration for health, and (4) promote behavior change by motivating and nudging children to drink more water (Fig. 2). Taking inspiration from successful school initiatives as well as involving parents and children through every step of the process may ensure better success.

Conclusion

Maintaining adequate fluid intake and optimal hydration is important for children for physiological reasons and for the adoption of healthy, sustainable drinking habits. Yet, data from the Liq.In⁷ cross-sectional surveys suggest that the majority of children do not drink sufficiently, particularly at school. This is further supported by studies in which urinary biomarkers of hydration were collected, showing that many children have highly concentrated urine. This situation is worrisome since studies have demonstrated a relationship between low fluid intake or insufficient hydration and cognitive performance

in children. Introducing water to children early and encouraging healthy drinking habits from the youngest age are therefore essential to support adequate fluid intake and optimal hydration in childhood and in later life. Within the family and school context, some actions may be put into place by adults to support healthy drinking habits in children:

- Offering water to children regularly throughout the day without relying on one's own thirst;
- Associating water intake with "moments" such as wake up, breakfast, morning and afternoon breaks to establish a routine;
- Making water accessible to children, even the youngest, at all times by using age-appropriate cups or bottles that children can access and drink from independently;
- Providing a positive parental drinking model for children at home and at school;
- Making water fun by various means such as drinking straws, fresh herbs or sliced fruits, sparkling water, personalized glass, or bottle;

- Introducing children to urine color and hydration assessment from a young age;
- Encouraging and educating children to drink and check their hydration before and after exercise, for example, using urine color;
- Asking children about water access, toilets facilities, and water- and toilet-related education at school;
- Establishing or improving water- and toilet-related policies at school.

Future research is needed to better understand barriers to drinking water in children and to identify factors that successfully encourage water intake in different contexts.

Disclosure Statement

J.H.B., C.M., I.G., and E.T.P. are full-time employees of Danone Research.

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