Total water intake and its contributors in infants and young children

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Abstract

Hydration is a particular concern for infants and young children due to their greater risk of dehydration. However, studies on their water intakes are scarce. The current survey aimed to analyse total water intake (TWI) in non-breastfed children aged 0·5–35 months compared with the adequate intake (AI) for the same age group set by the European Food Safety Authority and to examine the different contributors to TWI as well as beverage consumption patterns. Nationally representative data from the Nutri-Bébé cross-sectional survey were used to assess food, beverage and plain water consumption by age group over three non-consecutive days. With age, median TWI in 1035 children increased from 732 to 1010 ml/d, without differences between sexes, but with a great inter-individual variation, and the percentage of children who did not meet the AI increased from 10 to 88 %. Median weight-related TWI decreased from 136·6 to 69·0 ml/kg per d. Among infants, 90 % had a ratio of water:energy below the AI, similarly for about 75 % of toddlers. Milk and milk products were the main contributors to TWI, while the part of plain water increased gradually to be 25 % in the older toddlers, half of which was tap water. The beverage consumption pattern varied in types and timing, with little consumption of juices and sweetened beverages. Vegetables and fruits accounted for 20 % of TWI after the age of 6 months. These initial results, showing strong discrepancies between actual and recommended water intakes in young children, should help identify ways to increase children's water consumption.

Key words: Water intake: Infants: Young children: Beverage consumption: Food moisture

Water is an essential nutrient and a key molecule for cellular homoeostasis, metabolic processes, circulatory function and temperature regulation. Water makes up the largest body component and maintaining an optimal hydration level is fundamental for good health. Compared with children and adults, infants have a higher total water content of the body. From birth to 3 months of age, total body water volume decreases gradually from 73·3 to 56·5 % of body weight in boys and 73·2 to 55·6 % in girls; after that, it is relatively stable ($P = 0·001$)[1–5]. Infants have higher losses than older children or adults due to a higher surface area to body mass ratio[3–6] and initially to a limited renal concentrating ability[7–9]. Daily water turnover, meaning the replacement of body water that is lost in a day, decreases from 160 ml/kg (1–3 months) to 100 ml/kg (10–12 months), 65 ml/kg (3 years) and 40 ml/kg at 15 years of age[2]. Some water is also required for growth, and a growth rate of 15 g/kg per d results in a net storage of about 12 ml water[3].

Given that infants and young children are particularly susceptible to diarrhoea and vomiting and less heat tolerant, they have a more likely tendency for dehydration[10,11]. Moreover, they have difficulties expressing thirst, or their need for fluids (mainly water) and are dependent upon others to provide fluids.

Maintaining optimal hydration is a public health issue, especially in infants and young children, whose total water intake (TWI) per unit of body weight is about three times higher than that of adults[6]. In addition, some studies have pointed out several deleterious health outcomes related to low water intake, even in cases of mild dehydration (< 2 %)[12–14]. Despite this, water is often forgotten in daily dietary recommendations and some guidelines and nutrition surveys.

Total available water includes TWI and endogenous production coming from the oxidation of energy substrates (roughly 300 ml/d in adults) that would account for about 12 % of total water[5,15,16]. However, metabolic water production depends on the nature and structure of the substrates and

is proportional to energy expenditure. Therefore, its accurate assessment would require sophisticated research methods. Due to the impossibility to determine an average requirement, adequate intake (AI) levels for TWI have been established by national and international health authorities, especially the WHO, the Institute of Medicine and the European Food Safety Authority (EFSA)[5,16–18]. But accurate data on water intake in non-breastfed children are needed to set dietary reference values and inform researchers, parents, child careers and policymakers. Unfortunately, to date, children, especially the youngest ones, have been subject to little study, which, very often, has been related only to fluid consumption (milk and dairy products, plain water, other beverages and soups) or to drinking water (DW) only[15,19–42]. Using data from the Nutri-Bébé 2013 study[43], we aimed to report TWI and to analyse the different contributors to these intakes in French infants and young children (0–3 years) and to compare the observed intakes to the AI set by the EFSA[5,18]. The secondary aim of the present study was to describe fluid consumption patterns with the respective percentage of consumers and their drinking occasions.

Subjects and methods

Study design and participants

Secondary analysis was conducted on data collected in the Nutri-Bébé survey, an observational, cross-sectional study. Data collection was from January to April 2013 by the TNS SOFRES, an official opinion, and market research institute, which fulfils the following standard requirements: ESOMAR professional code of conduct and standards; ISO 20252:2012 international standard for market, opinion and social research; and the French data protection act (Loi 'Informatique et Libertés'), ensuring that respondents' personal identity is withheld. Moreover, TNS SOFRES appointed a data protection officer, the 'Correspondant Informatique et Libertés', who is the point of contact with the 'Commission Nationale de l'Informatique et des Libertés', the French data protection authority. Repeating TNS SOFRES is thus exempted, of the notification process to the Commission Nationale de l'Informatique et des Libertés as far as the data processing for which it is the data controller are concerned. The guidelines laid down in the Declaration of Helsinki (https://www.wma.net/wp-content/uploads/2018/07/DoH-Oct2008.pdf) were strictly followed by observing all the principles that may apply to an observational survey including registration, informed consent, absence of health risk, information about sponsors and potential conflicts of interests. Principle number 15, that is, submission to an ethics committee, was not required according to the French legislation, since the survey did not involve invasive procedures or therapeutic intervention. Full details of the survey methodology have been described in a separate paper[43] not involving fluid intakes.

In short, the survey recruited parents of children aged 15 d to 35 months, using a precise quota method weighed for the different regions of mainland France, town size, habitat, socio-economic characteristics, age and sex of the child. After offering a fully informed description of the survey, parents were asked for their consent to participate without any monetary incentive. To be included, children must have been born at term, have had a birth weight above 2·5 kg and should have been free from intercurrent or chronic diseases. A total of 1184 children were enrolled in the study, of whom 149 were fully or partially breastfed, that is, received infant formula in addition to breast milk, during the survey (online Supplementary Fig. S1)[43]. Due to the inability to assess the volume of mother's milk suckled, only the food and fluid consumption data from non-breastfed children were considered further. Participating children were stratified by age according to the key stages of child development and feeding patterns, as carried out previously in Nutri-Bébé surveys[43–45]. The age group cut-off points were: 0·5–3, 4, 5, 6, 7, 8–9, 10–11, 12–17, 18–23, 24–29 and 30–35 months. Each age group was defined by the first day of the starting month and the last day of the ending month.

The children's parents and/or caregivers were given a diary, a 1-l measuring jug, a photographic tool kit, kitchen measuring tools and scales to assess their child's food consumption. A trained investigator explained to parents and/or caregivers the use of these different tools and how to report the data. Subsequently, the parents and/or caregivers were asked to describe in a 3-d food diary the nature and the amounts of food and fluids the child consumed over a non-consecutive 3-d period, including one weekend day. They had to report in the diary the quantity (in g, ml or dose) served and what remained after consumption, as well as the ingredients of the food or drink. The intake occasions were noted and classified as follows: breakfast, morning snack, lunch, afternoon snack, dinner, at bedtime and during the night. These recordings over 3 d took place in between two face-to-face interviews with the TNS SOFRES investigators: the first to explain the procedure and the second to review the diary, check for completeness, clarify details and weigh the child (with just a clean diaper or underwear), using a Tefal Premiss PP1000VO scale with an accuracy of 100 g. Weights were compared with the WHO growth standard curves, leading to thirty-seven data points being considered unreliable because they deviated from the mean standard value by more than three Z-scores[43,46]. They were therefore not included in the calculation of the weight-based intake. Height was not measured, and consequently, the BMI could not be calculated. Both interviews were recorded using CAPI® software (Computer Assisted Personal Interviews). All data were recorded to maintain anonymity.

Water intake assessment

Secondary analysis of the intakes was performed by the non-profit government organisation Centre de Recherche pour l'Etude et l'Observation des Conditions de Vie – Research Center for the Study and Observation of Living Conditions. They assessed TWI by examining water intakes provided by DW and by all other fluids, including milk that, according to age, were given as infant formula (so-called starter formula), follow-on formula, young child formula (so-called growing-up milk), cows' milk and other beverages and moisture in food which were categorised as depicted in online Supplementary

Table S1. Besides tap water, bottled water was distinguished into mineral water and spring water, as defined by the European Parliament and the Food and Drug Administration[47,48]. The water contents of common beverages and of common foods were established using the Centre d'Information sur la Qualité des Aliments 2013 database developed by the Agence Nationale de Sécurité Sanitaire de l'Alimentation, de l'Environnement et du Travail[49]. For baby foods, specific for infants and young children as defined by the Commission Directive of the European Communities 2006/125/EC of 5 December 2006, the water content was calculated based on the average composition of the foodstuffs composing the product described in the Centre d'Information sur la Qualité des Aliments table. Overall, 50 493 foods or fluids consumption entries were identified.

Analysis of fluids and food consumption data

Previously published results[43–45] on population characteristics and energy and protein intakes are presented as means and standard deviation. Water intakes are expressed as median with interquartile range (Q1–Q3), range and mean values and standard deviations. Sources of water intake are described as mean percentage of contribution. In each age group, the fluid and food consumption values were calculated from the mean of each individual's contributions on the first, second and third day of the survey related to the size of the age group[43]. In the absence of average requirements determinations by official authorities, daily TWI was compared with the lowest values of AI set by the EFSA as they were the most recent and almost identical to those set by WHO and by Institute of Medicine (Table 1)[5,16–18]. Only the EFSA established AI related to body weight, and this only for infants younger than 7 months[5]. For infants in the first year, the EFSA AI was based on the average observed water intake from human milk in exclusively breastfed infants (100–190 ml/kg body weight per day). AI was derived from average observed intakes of human milk and typical complimentary food and beverages for older infants. For the second year of life, an adequate TWI of 1100–1200 ml/d is defined by interpolation, as intake data were not available until now. For the third year of life, AI was estimated from the reported average intakes to be 1300 ml/d for boys and girls.

SAS 9.2 software was used for statistical analyses (SAS Institute, Inc. http://support.sas.com/documentation/installcenter/922/). Differences in intake between sexes were tested in each age group with ANOVA. The two-sided type I error was set at 5 % for all the statistical tests.

Results

The final sample for the current analysis consisted of 1035 non-breastfed children.

The population characteristics[43], including the sex distribution and the mean body weight at the time of the survey, and the daily energy, protein and Na intakes[44,45] are shown in Table 2. The mean age of mothers was 30·8 (SD 5·4) years. Among mothers, 38 % were primiparous, 60 % were working

and 11 % lived without a partner. The mean number of people in the household was 4·1 (SD 1·3). The mean birth weight of children was 3·33 (SD 0·48) kg. The detailed distribution of weight by sex and age has been reported already[43]. Overall 88 % of children had a body weight between the 3rd and the 97th percentile of the WHO growth standards[46].

Total water intake

Daily total water intake. Median (25th, 75th percentile, range) daily TWI are depicted in Fig. 1, showing a median intake increasing slightly with age from 732 to 990 ml/d in the 10–11 months aged group and then being relatively stable. The mean TWI increased with age from 753 (SD 113) ml/d in the first age group to 1007 (SD 208) ml/d in the 10–11 months old infants. After that, it remained relatively stable to be at 1083 (SD 444) ml/d in the oldest group. The mean and median TWI of children over 1 year old were below the EFSA AI (online Supplementary Table S2). Of note are the important inter-individual variations within each age group.

Daily TWI tended to be higher in boys except for the 30–35 months group. This difference in favour of boys is however only significant in three age groups (5-month-old infants, +96 ml, $P = 0.002$; 6-month infants, +70 ml, $P = 0.049$; 18–23-month-old group, +132 ml, $P = 0.01$). The percentages of children who, according to age, did not achieve the lowest EFSA AI are given in Table 3. They were more than 20 % after 6 months of age, about 50 % in the second year of life and more than 80 % in the third year.

Total water intake per body weight. Overall TWI per body weight decreased with age, while inter-individual variability increased (Table 4). Compared with the AI set by EFSA[5], only about 10 % of infants aged 4–5 months and 25 % of the 6 months aged infants had a TWI/kg body weight below the proposed lowest limit (100 ml/kg per d). However, from 7 to 11 months, more than 25 % of infants had intakes below this limit, while there were more than 50 % in the 12–23 months aged group and more than 75 % in the 24–35 months aged groups.

Total water intake per energy intake. Total energy intake and energy intake per kg of body weight have been assessed previously and are given in Table 2[44]. The distribution of the observed water-to-energy ratio is depicted in Fig. 2. Overall, the median and mean ratio values were above 1, but they fell far short of EFSA AI, especially in infants as 90 % of them, and about 75 % of the toddlers, had a ratio below the AI (Table 1)[5].

Contributors to the total water intake

Contribution of each food group. The average contribution of each food group to TWI is a percentage in Fig. 3 and a mean quantitative value in online Supplementary Table S3. In general, the share of each fluid or food category to the TWI showed significant variability in each age group. Overall, fluid intake, including DW, all milk products, other beverages and soup, accounted for 76·8 % of TWI at 6 months, 66·8 % at the end of the first year of life, 72·4 % during the second year and 73·7 % during the third year of life with significant inter-individual

Table 1. Adequate intakes for total water set for boys and girls together by the WHO[16], the Institute of Medicine (IOM)[17] and the European Food Safety Authority (EFSA)[5,18]

Age group	WHO	IOM	EFSA	
0–6 months	700 ml/d	700 ml/d	680 ml/d	1500 ml/1000 kcal
7–11 months	800 ml/d	800 ml/d	800–1000 ml/d	
12–23 months	1300 ml/d	1300 ml/d	1100–1200 ml/d	1200 ml/1000 kcal
24–36 months			1300 ml/d	

Table 2. Population characteristics and reported daily dietary intakes of energy, protein and Na (*n* 1035)[43–45]. Body weights are given as mean values and standard deviations. Intakes are given as median values with interquartile range (Q1–Q3) and compared with the highest values of the corresponding EFSA dietary references (DRV)

Age (months)	*n*	% Boys/ girls	Body wt* (kg) Mean	SD	Energy intake (kJ/d)† DRV	Median	Interquartile range	Protein intake (g/d)‡ DRV	Median	Interquartile range	Na intake (mg/d)§ DRV	Median	Interquartile range
0·5–3	91	56/44	5·6	0·9	120·7	130·5	115·1–145·3	8	10·7	9·5–12·2	120	162	143–184
4	80	51/49	6·8	0·5	130·5	147·9	135·0–163·2	9	12·0	10·9–13·8	120	184	167–221
5	91	56/44	7·4	0·6	139·3	151·0	131·8–170·5	9	12·9	9·8–15·0	120	204	183–239
6	90	43 /57	7·9	0·5	143·2	161·1	141·9–179·0	9	16·7	13·9–20·0	120	282	228–383
7	77	51/49	8·4	0·5	154·2	171·0	155·9–183·5	11	18·7	15·8–21·3	370	327	275–437
8–9	77	56/44	8·9	1·1	159·9	177·7	158·9–203·7	11	22·8	18·5–28·2	370	448	349–554
10–11	82	54/48	9·4	1·1	174·0	195·4	173·7–226·7	11	27·0	21·5–35·5	370	587	434–774
12–17	121	50/50	10·4	1·8	182·6	212·2	185·9–242·6	11	33·8	27·5–41·2	370	780	586–1032
18–23	120	54/46	11·8	2·0	188·3	239·8	211·3–279·8	11	39·1	33·2–46·7	370	996	97–1367
24–29	125	55/45	12·9	2·8	216·8	235·3	194·9–277·2	12	40·2	33·1–49·1	370	1068	905–1376
30–35	81	50/50	14·1	2·9	245·5	243·8	218·3–287·5	12	41·4	35·0–47·9	370	1137	949–1492

* According to age, boys were on average slightly heavier than girls (NS).
† Average requirements.
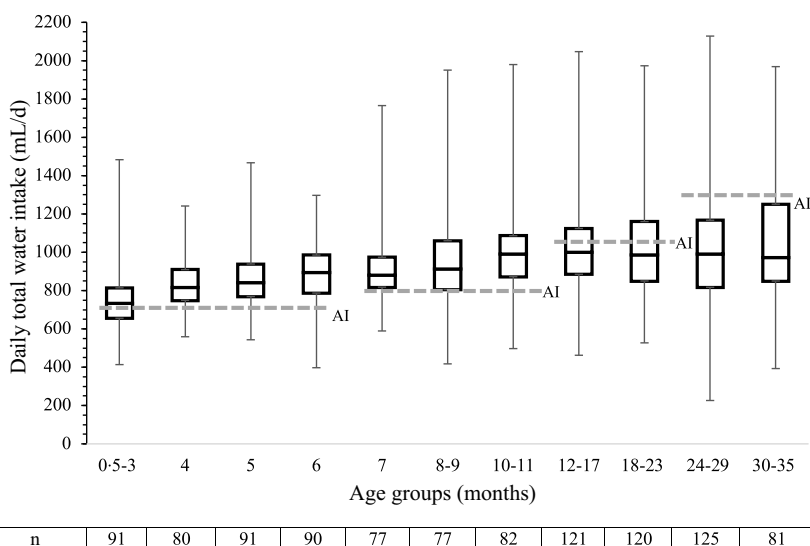‡ Population reference intake.
§ Adequate intake.

Fig. 1. Total daily water intake by age group (*n* 1035) in relation to the EFSA AI (———)[5,18]. The boxes represent interquartile ranges (25th and 75th percentiles); the central lines inside the box are the medians; the whiskers represent ranges (minimum and maximum value).

Table 3. Percentage of children (*n* 1035) who did not meet the lowest EFSA recommendations on adequate intake (AI) for total water intake[5,17]

Age groups (months)	0·5–3	4	5	6	7	8–9	10–11	12–17	18–23	24–29	30–35
EFSA AI (ml/d)	680				800			1100		1300	
% children < AI	33	14	12	30	20	24	12	51	50	88	84

Table 4. Daily total water intake per body weight (ml/kg/d) and per age group (n 998), expressed as median, Q1 (25th percentile), Q3 (75th percentile) and mean values and standard deviations

	Age group (months)										
	0·5–3	4	5	6	7	8–9	10–11	12–17	18–23	24–30	31–35
n	87	78	89	89	74	74	77	120	114	118	78
Q1	116·8	106·6	101·8	99·1	99·6	92·5	91·2	82·0	70·6	65·8	60·7
Median	136·6	121·6	115·2	109·1	107·1	104·9	106·4	98·6	87·3	80·3	69·0
Q3	156·1	136·9	129·5	126·4	119·3	124·8	119·0	114·5	101·7	97·0	90·8
Mean	141·1	122·4	117·0	113·4	111·6	109·2	108·9	100·7	89·0	81·9	74·7
SD	28·2	12·9	12·2	14·1	13·1	24·9	26·8	32·8	29·8	29·5	36·6
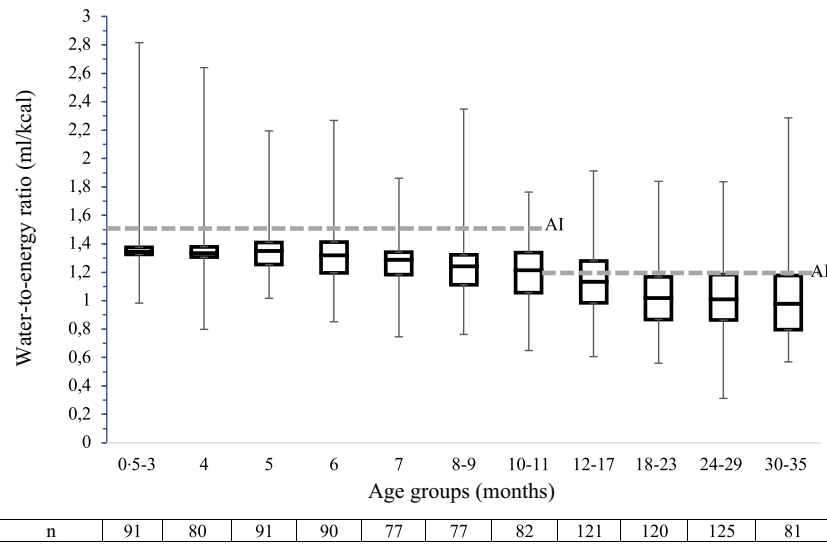
Fig. 2. Water-to-energy ratio (ml/kcal) distribution according to age (n 1035) in relation to the EFSA AI (———)[5]. The boxes represent interquartile ranges (25th and 75th percentiles); the central lines inside the box are the medians; the whiskers represent ranges (minimum and maximum value).
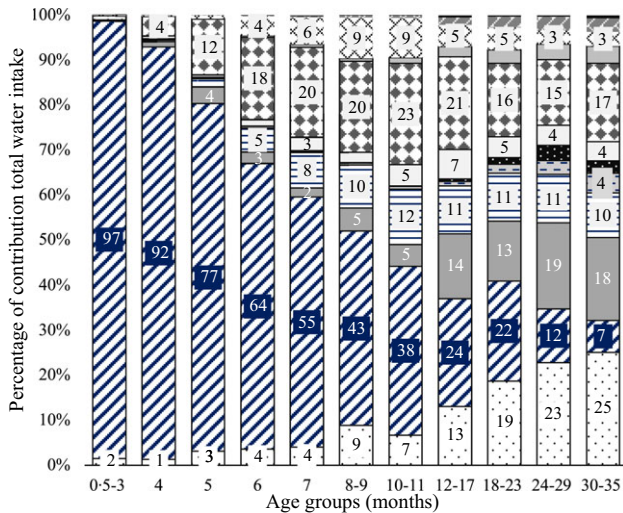

Fig. 3. Average contribution of each source (%) to total water intake (n 1035). Values in labels have been rounded to the nearest whole number. ■, miscellaneous; ▨, starch products; ⋌, industrial ready meals; ▢, meat, fish and eggs; ▤, vegetables and fruits; ▢, soup; ■, soda and sweet beverages; ▢, fruit juices; ▤, dairy products; ▤, cow's milk; ▢, formula; ▢, drinking water.

variability. For the same groups, food moisture accounted for 23·2, 33·2, 27·6 and 26·3 %. Detailed analysis of TWI by age group and food or fluid category showed that milk, including infant formula, follow-on formula and young child formula, and dairy products were the primary water intake source whatever the age (Fig. 3). The mean contribution of these milk products to TWI decreased from more than 97% of TWI in the 0·5–3 months age group to 71% at 6 months, 54·6 % in the 10–11 months age group, 46·1 % in the 18–23 months age group and 35·4 % in the 30–35 months age group. Overall, milk and dairy products were consumed by all the children with a change of type depending on age. DW accounted for more than 5 % of TWI after 8 months to reach a share of just above 25 % in the 30–35 months age group. From the age of 6 months, vegetable and fruit intake shared a significant part of the water intake, around 20 %, since almost 100 % of children consumed them. Fruit or vegetable juices were consumed by 2–3 % of infants younger than 4 months, 7–10 % of those aged between 4 and 6 months, 14–17 % of the 7–11 months group, about 30 % of the second year group and above 50 % of the 24–35 months old children. Up to 10 months, no infant consumed more than 90 ml of juices per day; after that, they were few to consume more than 90 ml or even more than 120 ml. Older than 18 months, approximately 5% consumed more than 120 ml of juice per day. Up to 1 year of age, the consumption of sugar-sweetened beverage (SSB) was in isolated cases only. Less than 15 % of children 12–23 months old and less than 30% of children

24–35 months old consumed SSB. Up to 18 months, no children consumed more than 90 ml of SSB per day; they were 5 % after that and 10 % after 2 years. On average, fruit and vegetable juices plus SSB accounted for less than 2 % of TWI before 18 months and 7 % of TWI at 30–35 months. Their respective median intake was then 20·0 ml/d (Q1–Q3:0·0–73·8) for fruit and vegetable juices and 0·0 ml/d (Q1–Q3:0·0–0·0) for SSB.

Water used for the reconstitution of formula or as a beverage. The amount of water used to reconstitute (infant formula, follow-on formula, young child formula) was reported as formula intake. Whatever the age, tap water was very rarely (less than 3 % of occasions) used to reconstitute formula. Parents would alternately and substantially use both types of bottled water equivalently during the 3 d of recording.

Intake of DW increased with age with an extreme dispersion of the results. However, the dispersion decreased, with age, given that the quartile coefficient of dispersion decreased from 1 to 0·42 from 6 months onwards (online Supplementary Table S4).

The proportion of children who reported DW increased with age from very few infants in early life to 90–100 % of children after 8 months. Less than 5 % of the infants younger than 8 months drank tap water; the children who drank bottled water were divided almost equally between mineral water drinkers and those drinking spring water. Most children of 8 months and more (90–100 %) drank water, with an increasing proportion of them, up to 58 % for the older group, who drank tap water.

Fluid intake occasions

The pattern of fluid consumption was very variable in types of beverages and timing during the day. Overall, most DW (30–60 %) was consumed during the afternoon snack. The lowest volume of DW was consumed at breakfast or during the night. Lunch and dinner were associated with less than 20 % of DW consumed and at bedtime. The peak occasion for consuming soup was at lunch before 6 months, followed by dinner and the inverse after 6 months. Most fruit or vegetable juices were consumed first with afternoon snacks at all ages, then with the morning snack or lunch in infants younger than 9 months, and breakfast or morning snacks in older children. They were very rarely drunk with dinner and never later. The consumption habits of SSB were the most disparate during the day, consumed in the afternoon or during main meals but never at bedtime or during the night. Figure 4 provides a visual representation of the consumption patterns in the 30–35 months age group of children with the biggest drinkers.

Discussion

The present analysis of TWI from all sources provides several new and original insights for water and other fluid consumption patterns for infants and young children. Earlier studies were limited to reporting either only fluid consumption[21,29,32] or data from children greater than 1[15,19,23,31] or 3 years of age[20,24–28,30,33–42].

Our results in children 2–3 years old are comparable to those of the German DONALD study[15] but lower than those found in the US NHANES study or one from Mexico[19,23]. The effect of sex on the intake was neither consistent nor very pronounced in our sample, as reported in the Mexican survey[23] or in older children[25,26]. The AI set by Institute of Medicine or EFSA were similar for both sexes[5,17,18]. The proportion of children with intakes below the AI increased to more than 80 % after 2 years. However, these results must be weighed because the EFSA AI are mean values given respectively for entire age groups 0–6, 7–12, 13–24 and 25–36 months. Thus, they do not allow us to estimate the probability of water intake inadequacy, while groups with mean intakes at or above the AI can be assumed to have a low prevalence of inadequate intakes.

On the other hand, our results of mean TWI per kg of body weight were close to those reported on water turnover by Fusch *et al.* in 1993 in the same age groups[3]. Three-quarters of the infants and most toddlers had a TWI/energy ratio below the AI set for their age[5], but overall our results were higher than those reported in Mexico[23]. This in line with the high energy densities of the diets we reported previously as increasing with age and the introduction of solid foods, on average from 15·3 to 20·3 kJ/100 g (64 to 85 kcal/100g) and even over 24100 kJ/g (24kcal/100g) in more than 10 % of children older than 18 months[44]. The gradual increase of non-adherence to the AI after 6 months of age was linked to the increasingly significant share of solid food with age. The decreasing consumption of formula or milk was not compensated for by the drinking of water. The reported median age for the introduction of solid food in the study sample was 4·9 (Q1–Q3: 3·9–5·9) months[44].

The individual requirements for water are related both to energetic consumption and to water losses via excretion, mainly urine and secretion/transpiration. The glomerular filtration rate is limited in early life and rises gradually to reach adult rates by 18–24 months[50]. The minimum water required for urine depends on the daily solute excretory load, primarily determined by the diet content, nitrogenous compounds and electrolytes[7], while the maximum urinary concentration capacity is limited in infants[8,9]. Our study population protein intakes were shown to reach 1·4 times the average requirements before 3 months, two times at 8–9 months and > 4 times at 30–35 months[44]. Na intake reaches twice the AI values in the second year and three times in the third year. Intakes of Ca, P and Mg also exceeded the corresponding reference values[45]. This would suggest a drive towards higher TWI intake than assessed to facilitate solute excretion. This finding, paired with reports of numerous deleterious health outcomes related to low water intake in children and adults, even in cases of mild dehydration, warrants further investigation. Young children considered particularly at risk of impaired cognitive function remain an understudied population relative to the known positive effects of hydration on cognition[51]. The long-term consequences of under-hydration in early life, particularly related to chronic kidney diseases following Brenner's hypothesis, have not been studied so far[52].

Overall, after the first semester of life, fluids (milk and dairy products, DW, other beverages and soups) accounted for about 70 % of the TWI and food moisture for 23–33 %. The contribution of food moisture was similar to that reported by the Institute of
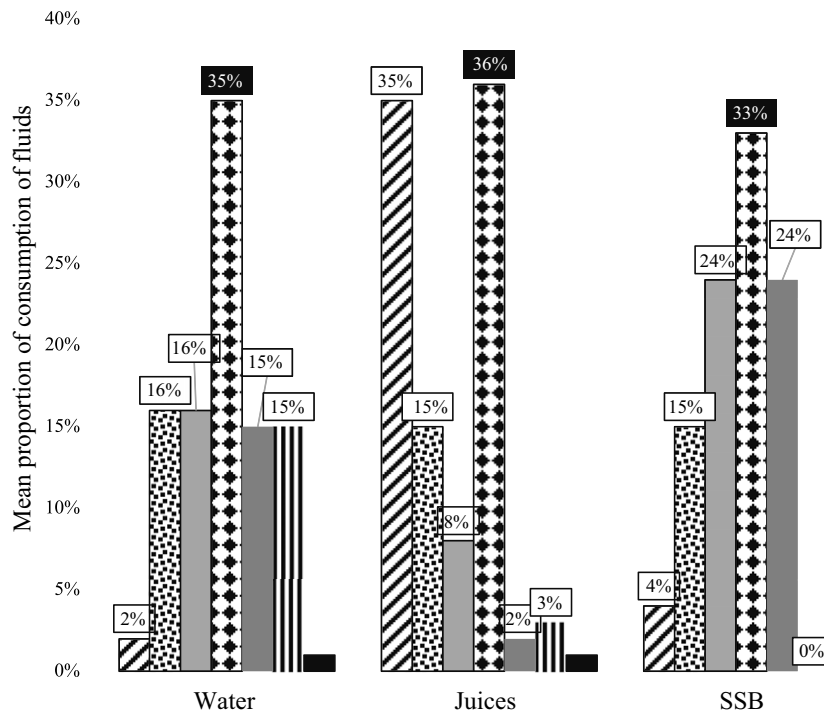
Fig. 4. Mean proportion over 3 d recording of consumption of plain water, 100 % fruit or vegetable juices and sugar-sweetened beverages (SSB) on each occasion during the day in the 30–35 months old group of children (*n* 81). ▨, breakfast; ▨, morning snack; ▨, lunch; ▨, afternoon snack; ▨, dinner; ▮▮, at bedtime; ▪, night.

Medicine (about 30 %), higher than that by the EFSA (20 %) and lower than in older children (40 %)[5,17,28]. Whatever the age, milk as formula or cows' milk and dairy products represented the primary source of water intake, decreasing with age as has been shown by others[15,19,23]. DW accounted for only one-fourth of this intake at 30–35 months, while fruit juices and SSB accounted together for a maximum of 7 % of intake, below that reported elsewhere for young children[15,21,23,31,40]. After 8 months of age, nearly all children drank water, while a relatively small number of them consumed juices and/or SSB, contrary to what has been reported in other studies and other countries[22,24,29]. Tap water consumption was more prevalent among the older children, while the youngest infants were more likely to drink hypotonic mineral water. Bottled water was also the main plain water used for the reconstitution of the formula. Bottled waters consumed were among those labelled for infants in accordance with the European directive and the Agence Nationale de Sécurité Sanitaire de l'Alimentation, de l'Environnement et du Travail criteria[47,53]. Tap water quality in France relies on strict standards edited by the Ministry of Health and the Agence Nationale de Sécurité Sanitaire de l'Alimentation, de l'Environnement et du Travail accounting for European and WHO recommendations[54–58]. At the time of the survey, 97·2 % of the French population was being supplied with water of good microbiological quality[59], and respectively 98·6 and 93·1 % were provided with water that constantly met the quality limit for nitrates and pesticides, according to the European directive 98/83/EC[54,59]. Of concern might be the content of tap water in other potential contaminants (Al, Ba, Cu, Fe, Mn, Na, Ni, Pb or Sb) which have been shown to exceed the maximum levels recommended by authorities[60]. The possible impact on the health of such results has not yet been assessed.

Our study's fluid consumption pattern may be considered surprising even when compared with those described by others[32]. Reassuring is the very low consumption of juice or SSB at bedtime or during the night. The quite low consumption of juices and SSB in the present survey is in agreement with, and even lower than, the recommendations of all the guidelines, which do not indicate the amount of plain water to drink[61–64]. High sugar content in juices contributes to increased energy consumption and the risk of dental caries. However, a meta-analysis found only a small effect of a single serving of fruit juice on BMI change[65]. Children who drank juices, at least once a day, at age 2 were later less likely to drink milk regularly but more likely to consume juice and SSB[66,67]. Unlike juices, SSB intake has been associated with higher BMI Z-score in children over 2 years of age[38,68] and higher blood glucose and TAG in children aged 4 years and more[69]. Parental modelling and feeding practices, as well as low socio-economic status, are among determinants of SSB consumption in young children[70]. In the present study, fruit and vegetable consumption from the age of 6 months took a significant part of TWI, around 20 %, confirming their role in improving hydration status.

Several limitations to this study should be acknowledged. Most of them have already been widely discussed in a previous publication[43]. Assessing fluid intakes of breastfed children was not possible. No data on temperature or humidity were gathered during much of the winter and early spring period of data collection, nor were seasonality considered. Mainland France has a

temperate climate, with a 13·7°C average temperature difference between summer and winter. No differences in TWI in American children aged 2–19 years were found between seasons[19]. No association was shown between temperature and TWI in children aged 1–10 years, contrary to what is reported in teenagers and adults, and a weak association was found between DW intake and temperature[71]. Sweat production in young children is indeed considerably less than in adults under similar climatic and activity conditions even when sweating rate is corrected for skin surface area[17]. Our survey does not allow an estimate of any inadequacy as we were not able to measure any morning weight variations nor assess urine volume, colour, number of voids or osmolality[72]. From thirty-two studies on children aged 4–13 years reviewed by Suh *et al.*, only eleven studies reported both water intake and hydration status without assessing the relation between the two[41]. Despite these limitations, our study exhibited several important strengths in addition to its originality. It represents a significant, nationally representative data source with an important sample size. The methodology we used and considered as validated[43] was in line with the EFSA and the recent WHO guidelines[73,74] and has been estimated as a suitable method to assess water intake even if a 7-d diary seems to be more relevant[75,76]. Data analysed in our study were collected using rigorous methods to measure water intake. The fact that the children were completely dependent at this age on the parents and/or caregivers for their intake strongly suggests that all the events have been recorded.

Conclusion

Hydration is a particular concern for young children. Due to the scarcity of early childhood surveys assessing TWI and its sources in infants and young children studies as this one become very important. The present study has provided valuable new data on infant and children's TWI as well as on the different sources of this intake according to age. We observed that an increasing number of children failed to meet the AI for water intake with age, raising concerns about their hydration status. However, of note is that all reference values, set as AI, have been defined derived from observed intakes, and sometimes by interpolation, without considering the hydration status nor the possible health consequences. Therefore, no conclusion on the inadequacy of the intakes we reported may be drawn, except that intake at or above the AI may be considered as adequate in conditions of moderate environmental temperature and moderate physical activity levels. Our results suggest that children's water consumption should be monitored more closely by health professionals, caregivers and perhaps even parents. The results can be used together with those of older children to develop new approaches to improve the overall quality of infants' and children's diet and their hydration status by encouraging parents to offer water to drink more often after the introduction of solid food and to favour demand-feeding before. It is worth noting that the intakes of juices and SSB were lower in the current analysis than in other studies. During this early phase of life, dietary patterns begin to form and can influence later food and drinking preferences and health. This underlines the importance of parenting practices, especially availability of healthy and unhealthy beverages at home, permissiveness towards sugared drinks and lack of self-efficacy to refuse SSB consumption, as well as encouragement to drink plain water.

Future research should aim to assess TWI together with hydration status and to examine the relation between optimal hydration status of young children and disease prevention. This should allow future guidelines to give more precise reference values, while the training of health professionals and textbooks should give more attention to water requirements and the importance of drinking plain water.

Supplementary material

For supplementary materials referred to in this article, please visit https://doi.org/10.1017/S0007114521003469

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