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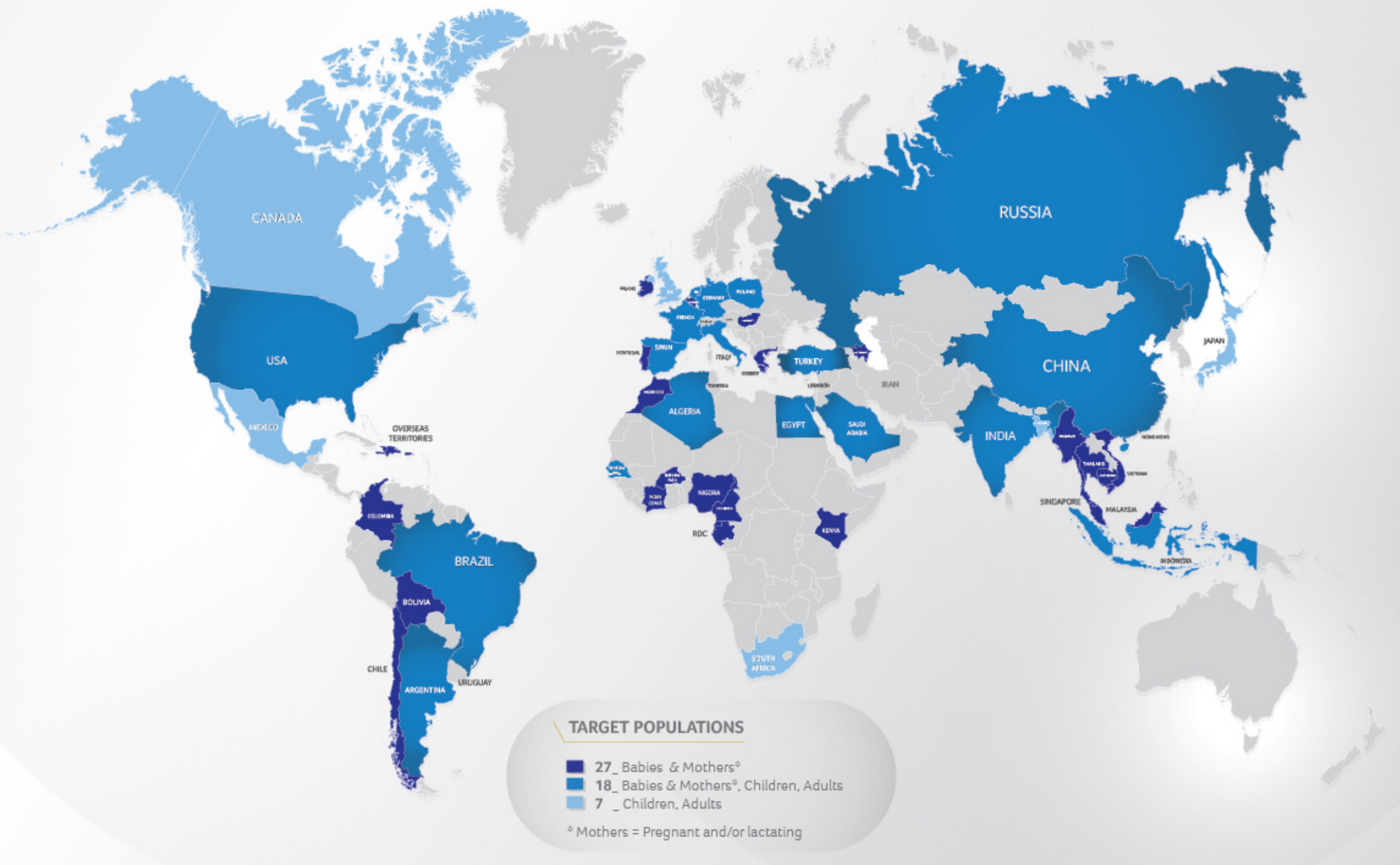
NutriPlanet program objective is to describe and get insights in the local nutrition and health status of specific populations.

The program compiles comprehensive dossiers of the nutritional data and public health situation in a country, and undertakes interviews with experts to better understand the local context.

These data are shared with the scientific community through publications or conferences, carried out by Nutricia Research scientists or their academic partners.

The NutriPlanet program has been implemented in 52 countries worldwide so far, among which 45 have a focus on pregnant & breasfeeding women and 0-3 year old children.



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NUTRITIONALS CHALLENGES AND OPPORTUNITIES DURING THE WEANING PERIOD AND IN YOUNG CHILDHOOD.

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Keywords: Weaning period · Early years · Feeding habits · Toddler · Diet · Nutrition · Transition

Abstract
The early years of life are a period of very rapid growth and development. In this critical phase, food preferences are formed which carry over into childhood and beyond and foundations are laid for a healthy adult life. Excess energy, imbalances in macronutrient quality, and nutritional deficiencies may form inappropriate nutritional signals, leading to metabolic disturbances and affecting the obesity risk. For instance, the intake of protein and sugar-sweetened beverages in young children has been associated with an increased risk of overweight and obesity. In reality, scientific reports have shown that the dietary intakes of vegetables, α-linolenic acid, docosahexaenoic acid, iron, vitamin D, and iodine are low and the intakes of protein, saturated fatty acids, and added sugar are high in young children living in Europe. A focus on improving feeding habits and approaches to support more balanced nutritional intakes early in life may have significant public health benefits.

Introduction

A Phase of Rapid Growth and Development
The first period of life is characterized by very rapid growth and development. Many organs including the gastrointestinal tract, pancreas, adipose tissue, and brain are still in development throughout infancy and young childhood. The body size doubles and the body weight increases 5-fold between birth and 3 years of age. Due to the rapid growth and development of the child, the (relative) nutritional requirements are high. Figure 1 gives an overview of the additional nutrient needs of a young child (1–3 years of age) compared to an adult (per kg of body weight) [1].

Relevance of the Transition Period: From 'Milk Only' to a More Diversified Diet
In this critical phase of life, the child's diet rapidly changes. While it is initially primarily milk based, solids are gradually introduced to the diet and finally the child will eat the family diet. A recent study [2] comparing the early development of BMI between normal weight and overweight children at the age of 8 years clearly showed that BMI development already started to differ significantly between groups during the first year of life and built up consistently after. No evidence of a specific critical period of development of overweight was observed. In a small longitudinal study by Péneau et al. [3], it was suggested that the beneficial effects of breastfeeding on later body fatness could be counteracted by an imbalanced diet after the breastfeeding period, a finding corroborated by recent findings of the Generation R Study [4]. These findings indicate that deviations in the developmental pathways leading to childhood obesity are not limited to any specific period in childhood, which in fact supports a focus on appropriate nutrition and behavioral intervention strategies throughout childhood [5, 6]. It is thought that the maturation of organs is adapted to the nutritional environment in this critical period of development. An excess of energy, imbalances in macronutrient quality, and nutritional deficiencies are negative nutritional signals which may lead to, for example, metabolic disturbances or the development of obesity [7–10].
Early life is also a crucial phase for the development of healthy eating habits. With repeated exposure and an available variety, the child learns to accept many different tastes [11–13] and these preferences subsequently carry over into childhood and beyond [14–17].
In this review, we discuss the nutritional reality of older infants (aged 6 months to 1 year) and young children (aged 1–3 years) in Europe and the possible consequences of different nutritional challenges for metabolic development.

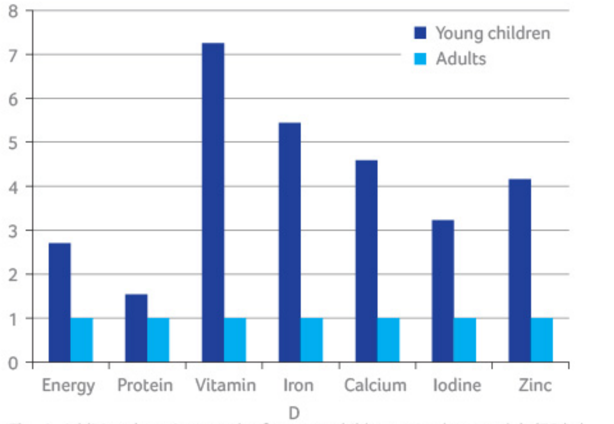

Fig. 1. *Additional nutrient needs of a young child compared to an adult (70 kg) per kilogram of body weight. For example, a young child needs 5.5 times more iron per kilogram of body weight com-pared to an adult.*

Methodology
To obtain information on the diet and nutrient intakes of young children in European countries, an extensive literature review was conducted. This literature review included structured searches for relevant published literature using a range of healthcare-related databases (PubMed, MEDLINE, Pascal, and Web of Science) as well as grey literature obtained from international and national organizations [e.g. the Food and

Agriculture Organization, UNICEF, the World Health Organization (WHO), the US Agency for International Development, the CIA World Factbook, the World Bank, and websites of ministries of health and NGOs]. The information on diet and nutrient intakes obtained from this literature review was compared to nutritional recommendations. Reference values given by the European Food Safety Authority (EFSA) [18–21] were used when available; otherwise, intakes were compared to recommendations of the Nordic Council of Ministers [1].

Results

Nutritional Intakes in Late Infancy and Young Childhood

The literature review showed that the dietary intakes of vegetables, n–3 fatty acids, iron, vitamin D, and iodine were consistently lower in older infants and young children, whereas the intakes of protein, saturated fatty acids (SFA), sodium, and free sugar were often higher than recommended.

Vegetables

Vegetables are important sources of vitamins and minerals, and diets rich in vegetables are known to help protect against disease [22, 23]. The recommended amounts of vegetables differ between countries but are generally around 75–100 g at 1 year and increase to about 125–150 g at around 3 years of age [24, 25]. Vegetables tend to be less well accepted by infants and young children, most likely due to their innate liking for sweet tastes. We found that vegetable intakes in European infants and young children were often lower than the recrecommendations (Fig. 2) [24-30].

n–3 Fatty Acids

The dietary recommendations of the EFSA for essential fatty acids (EFA) are [18]:

- α-linolenic acid (ALA): adequate intake of 0.5% of energy (en%)
- linoleic acid (LA): adequate intake of 4 en%
- docosahexaenoic acid (DHA): adequate intake of 100 mg/day for infants and young children (aged <2 years)
- DHA and eicosapentaenoic acid (EPA): adequate intake of 250 mg for children >2 years of age.

The limited information found in the public domain on the intake of EFA indicates that intakes are below or close to the lower end of the recommended intake. Especially intakes of EPA and DHA are far below the recommendations. For instance, in Belgium, children aged 2.5–3 years consumed 0.5 en% (0.8 g) ALA, 4 en% LA, 20 mg EPA, and 40 mg DHA per day. Austrian children aged 3–6 years consumed 0.5 en% (0.8 g) ALA, 20 mg EPA, and 80 mg DHA per day [18].

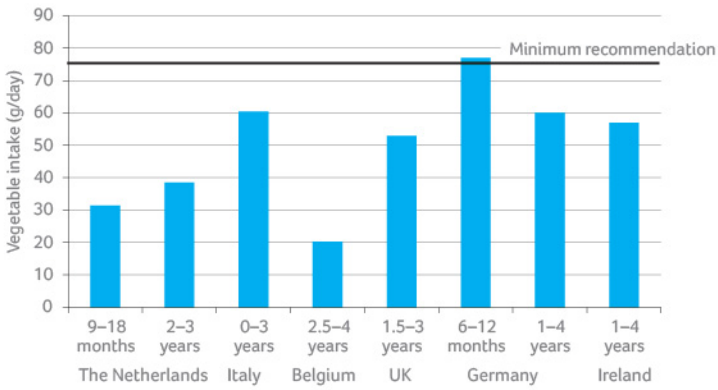

Fig. 2. *Vegetable intake of older infants and young children in European countries [24–30] compared to recommendations.*

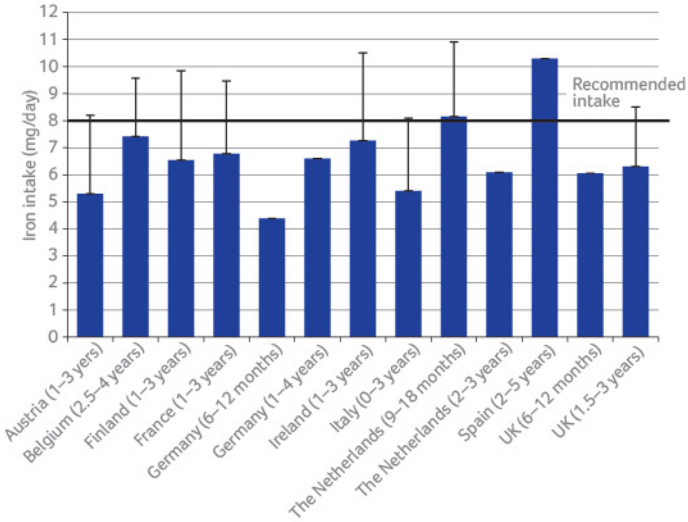

Fig. 3. *Iron intake of older infants and young children in European countries [25, 28–30, 33–41] compared to recommenda-tions [1].*

Iron

Infants and children have higher iron requirements during the period of fast growth [31], but many older infants and young children do not consume large quantities of iron-rich foods such as red meat and green leafy vegetables. A modeling study even concluded that it is impossible to achieve the recommended iron intakes with a diet completely conforming to dietary guidelines for infants/young children [32].

The average daily iron intake of older infants and young children in European countries was found to be around 6–7 mg/day [25, 28–30, 33–41] and thus was only slightly lower than the recommended value of 8 mg/day **(Fig. 3)** [1].

Despite the small intake gap, an inadequate iron intake may still be relevant as the brain is in rapid development during this period of life. Symptoms of iron deficiency (anemia) may be fatigue, lack of energy, headache, trouble sleeping, loss of appetite, paleness, reduced resistance to infection, and poor memory. In 6-month-old infants, iron deficiency anemia has been found to be associated with adverse effects on important measures of central nervous system development at 12 and 18 months [42].

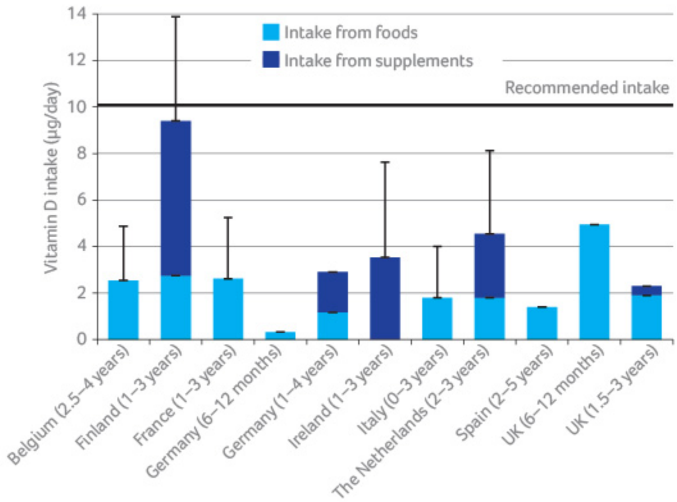

Fig. 4. *Vitamin D intake of older infants and young children in European countries [25, 29, 30, 33–37, 39–41] compared ommendations [1].*

Vitamin D

As indicated above, young children need 7 times more vitamin D per Kilogram of body weight **(fig. 1)** and 2.5 times more vitamin D per 100 kcal of food intake compared to adults [1]. Inadequate vitamin D status [25, 29, 30, 33–37, 39–41] and a deficient vitamin D status in older infants and young children have been observed in virtually all countries in Europe [43–46]. The current consensus based on these findings is that vitamin D should be regarded as a key nutrient for these age groups. Most foods only contain traces of vitamin D, with the exception of oily fish, which is, however, not frequently consumed by older infants and young children. A number of Western countries recommend vitamin D supplements, but compliance with the use of supplements has been found to be low, i.e. 10–50% [47–50].

Iodine

Inadequate iodine intakes and a deficient iodine status have been observed in young children in several European countries, among which are Germany, Austria, France, the Netherlands, and Turkey [25, 38, 51, 52], whereas in other countries (e.g. the UK) the daily iodine intakes meet the recommended value of 70–90 µg [53, 54]. This could be related to the iodine levels (declared) in cow's milk, which vary greatly throughout the different seasons and between regions. For example, reference values for cow's milk in different countries range from 3.3 µg/100 g in Germany, through 7 µg/100 g in the Netherlands, and up to 31 µg/100 g in the UK.

Protein

From 0.5 to 3 years of age, the required en% from protein decreases from around 6 to 4.5 en% as recommended by the EFSA [20]. The EFSA also stated that the current data are insufficient to establish a tolerable upper intake level for protein and concluded that intakes of up to twice the requirement (~10 en %) are regularly consumed from mixed diets and are to be considered safe [20]. Agostoni et al. [55] stated in a commentary paper by the ESPGHAN Committee on Nutrition that, although not entirely consistent, protein intakes ≥ 16 en% between the ages of 8 and 24 months may be associated with later overweight, whereas such associations were not seen with protein intakes <15 en%. Protein intake levels in older infants and young children were found to be close to this proposed upper limit for most countries **(fig. 5)** [24, 25, 28–30, 33–35, 37–41]

According to a recent systematic literature review carried out as part of the 5th revision of the Nordic Nutrition Recommendations, there is suggestive, albeit limited, evidence that the intake of animal protein, especially of dairy origin, has a stronger association with growth than the intake of vegetable protein [56]. In our analysis, however, limited information was available on the source of protein intake, i.e. vegetable versus animal protein.

Saturated Fatty Acids

In European countries, the average intake of SFA in older infants and young children is 11–13 en%, which exceeds the recommended maximum intake level of 10 en% **(fig. 6)** [24, 25, 28–30, 33–35, 37–39]. Low dietary intakes of SFA, i.e. levels <10 en% and preferably lower [1, 18] are recommended to reduce the long-term risk of heart disease [18]. Even at a young age, high dietary intakes of SFA have been shown to increase plasma total and LDL cholesterol concentrations and could enhance vascular lipid deposition and the ocurrrence of early

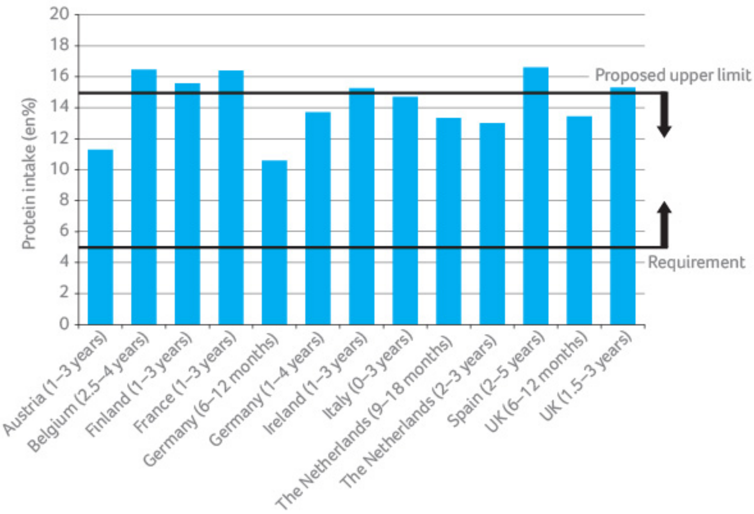

Fig. 5. *Protein intake of older infants and young children in European countries [24, 25, 28–30, 33–35, 37–41] compared to the average requirements [20] and the pro-posed upper limit [55].*

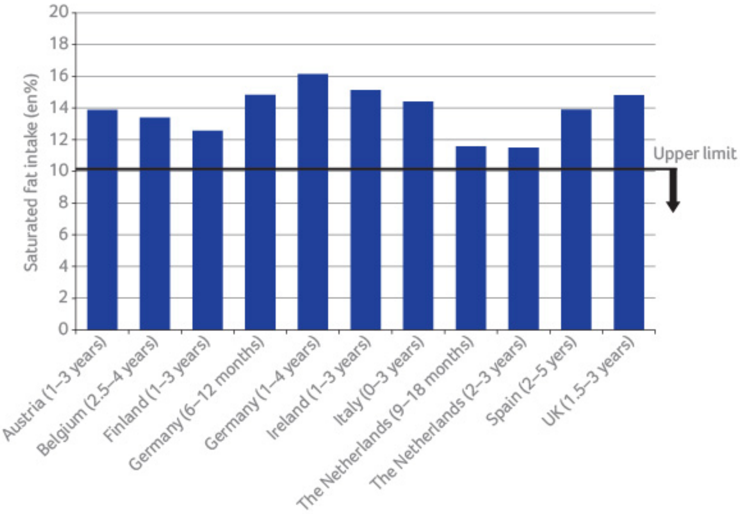

Fig. 6. *SFA intake of older infants and young children in European countries [24, 25, 28–30, 33–35, 37–39] compared to the upper limit [1, 18].*

vascular lesions [57–60]. In the Special Turku Coronary Risk Factor Intervention Project (STRIP), 1,000 healthy infants were randomized to a low-saturated-fat, low-cholesterol diet counseling group and a control group and were followed every 6–12 months throughout childhood. The results showed that cholesterol levels were significantly reduced throughout childhood and endothelial function was improved in 11-year-old boys randomized to the intervention group. There were no effects on growth, language skills, or motor functioning [58, 60].

Sodium

The habitual intake of sodium for all populations across Europe, including young children, is high **(fig. 7)** [25, 29, 30, 33, 34, 37–41] and exceeds the amounts required for normal function [1]. The sodium intakes of 1- to 3-year-olds range from 950 mg in Germany to more than 1,800 mg in Belgium and exceed the recommendation of 0.5 g/MJ for 1- and 2-year-olds. From 2 years of age onwards, the Nordic Council of Ministers set an upper limit of 1,400 mg of sodium per day, which is exceeded in both Belgium and Spain, i.e. the countries that included slightly older children.

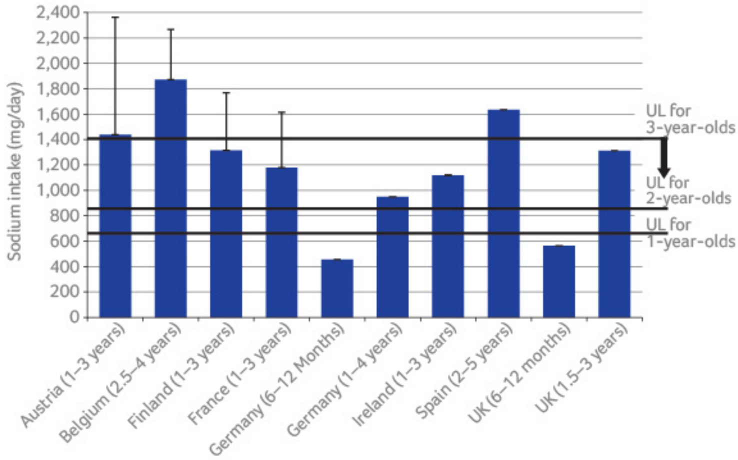

Fig. 7. *Sodium intake of older infants and young children in European countries [25, 29, 30, 33, 34, 37–41] compared to the upper limits (UL) [1,18].*

Already at the beginning of early childhood, the systolic blood pressure rises with increasing sodium intakes. Blood pressure measured in childhood predicts the blood pressure level and even the development of early atherosclerosis in adulthood [1]. It may be important to limit the sodium intakes in infancy and childhood to prevent children from becoming accustomed to and having a preference for a diet with a relatively high sodium content later in life.

Free Sugars

The different definitions that have been used to assess (added) sugar intake in the population make it difficult to compare sugar intake levels among European children. For example, in the UK the term 'non-milk extrinsic sugar' is used [30], whereas in Finland they refer to 'sucrose' [33] and in the Netherlands to 'sugar and confectionery' [24]. However, generally, older infants and young children consume much more free sugars, i.e. sugars that are added to food by the manufacturer or consumer, as well as sugars that are naturally present in honey, syrups, and fruit juices, as the recommended 10 en% as recently proposed by the WHO. The WHO even suggested that a reduction to <5 en% would have additional benefits [61]. For example, in Irish preschoolers the intake of sugar is 50 g/day, which equals about 19 en% [29] compared to the recommended 5-10 en % (fig. 8) [24, 29, 30, 33].

Free sugars are not essential for infants and young children as their diet contains many sources of other carbohydrates. It is important to limit the intake of free sugars in the diet of infants and children for 3 reasons.

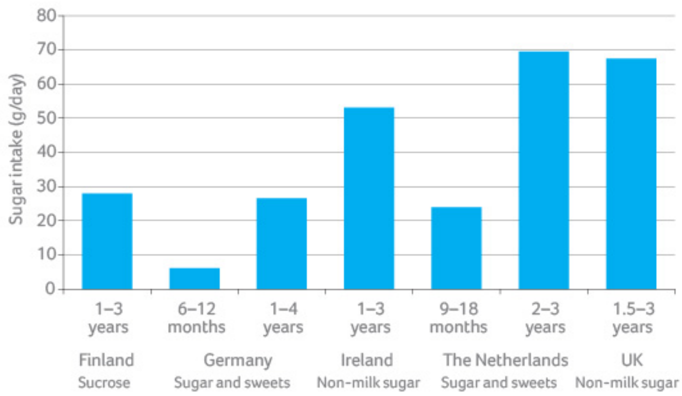

Fig. 8. *Free sugar intake of older infants and young children in European countries [24, 29, 30, 33].*

Firstly, free sugars are merely added for their sweet taste. Early life is a sensitive period for the development of food preferences that carry over into adulthood, and exposure to sweet tastes early in life may lead to a preference for sweet tastes later in life [16, 62]. Secondly, sweet products generally have a poor nutritional profile, i.e. they contain socalled 'empty calories', and it has been demonstrated that children with a high en% coming from sugars have lower intakes of micronutrients (i.e. calcium, zinc, thiamin, riboflavin, niacin, and folate) and dietary fiber [63–68]. Thirdly, products containing free sugars are known to increase the risk of dental caries in children [69]. The first step in the pathogenesis of dental caries is infection with the bacterial strain Streptococcus mutans [70], and it has been shown that this bacterium produces more acid with sucrose and glucose compared to milk sugar lactose [71, 72]. Finally, the consumption of sugar, and especially sugar-sweetened beverages, has been linked to the onset of childhood obesity [73].

Increased Risk of Childhood Obesity

The results of our evaluation showed a number of discrepancies between the recommendations for these young age groups and the real nutrient intakes in many European countries. Especially the imbalances in macronutrients, that may also drive some of the reported micronutrient deficiencies, can be a concern. There has been a dramatic increase in the prevalence of childhood overweight and obesity in the last 3 decades worldwide [74], and this may be associated with higher prevalences of cardiovascular and metabolic diseases later in life [75]. Although initially 'developmental origin of adult health and disease' (DOHaD) studies almost exclusively focused on the role of the *fetal* environment noncommunicable disease risk, it has become increasingly acknowledged that the window of programming extends into the (early) postnatal period [76–78].

Imbalances in nutrient intake may be relevant as they may challenge optimal organ growth and development of function during this postnatal period. The development and (functional) maturation of many (metabolic) organs including the gastrointestinal tract [78], brain [79], pancreas [80], and adipose tissue [81] continue for a considerable time after birth. For instance, adult differences in adipose cell numbers between lean and obese people gradually develop during childhood, already showing a 2-fold difference in the number of cells at the age of 2 years [82].

Some specific epidemiological and animal findings also support the relevance of the postnatal period as an independent contributor to the later disease risk. Initial studies of the Dutch famine showed a clear distinction between early pregnancy and late pregnancy exposure and later (disease) outcomes [83]. However, also women exposed to the Dutch famine between the ages of 0 and 9 years showed increased type 2 diabetes and overweight compared to unexposed women [84, 85]. These observational data are supported by an analysis of individual growth trajectories showing that weight gain between 0 and 2 years of age is most predictive of the later adiposity risk [86]. Recent data from the Generation R Study confirm the specific contribution of postnatal growth to the risk of overweight and obesity at the age of 6 years [87].

Animal studies have shown that [88] low protein in the postnatal diet reduces the adult fat mass, whereas the same diet during the fetal period is associated with adverse outcomes in adulthood. Similarly, moderate energy restriction during lactation has been shown to protect against enhanced adult fat accumulation in rats, whereas energy restriction during gestation has had the opposite effect [89]. These observations illustrate that growth depends on different fuels in fetal and postnatal life and is related to the timing of the development of individual organs and their nutritional needs during these different stages. Adequate nutritional intakes to support these different periods of organ growth and functional maturation are essential to achieving optimal organ capacity.

The Toddler Period: Diet and Obesity Risk

An important part of the daily energy intake during the first 3 years of life is derived from dietary fat. During the first 4–6 months of life, human milk (or infant milk formula) is the sole source of nutrition for the infant, providing 40–50 en% as fat. Dietary lipids provide energy for growth, supply the EFA LA (C18: 2 n–6) and ALA (C18: 3 n–3), and ensure adequate absorption of fat-soluble vitamins. Between 6 months and 2 years of age, the WHO recommends 30–40 en% from fat, although it was recently suggested that the energy derived from fat should be gradually reduced to a maximum of 30% to better match energy requirements and reduce the weight gain velocity according to the latest reference growth standards.

Observational data have linked low fat intakes at 10 months and 2 years of age to increased trunk body fat deposition and higher leptin resistance in young adulthood, supporting the significance of fat as the main energy provider in the early diet [90]. These data also clearly illustrate that the nutritional requirements to support optimal growth and development at this age differ from those advised for older children and adolescents.

A high protein intake at the ages of 12 and 18–24 months was independently related to a higher BMI and percentage of body fat and to a higher risk of having a BMI or percentage of body fat above the 75th percentile at the age of 7 years. The quality of the protein may be relevant as well, as both total protein and a high intake of animal but not vegetable protein were associated with increased body fat at 7 years [91, 92] .

Studies conducted in populations of children have demonstrated positive associations between the intake of sugar and BMI development [93–95]. However, the number of studies investigating the relationship between the total sugar intake in children and the obesity risk is small, likely related to the fact that limited sugar intake data are available.

Frequent exposure to foods and beverages containing sugar may have longer-term effects that could contribute to the risk of developing childhood obesity, but not all scientific evidence is consistent. In infants with a poor nutrient status, the intake of products high in sugar has been associated with a potential risk of developing micronutrient deficiencies due to their lower nutrient density compared to products lower in sugar [63–68] .

Discussion and Conclusion

In summary, the dietary intakes of vegetables, n–3 fatty acids, iron, vitamin D, and iodine are low and the intakes of protein, SFA, sodium, and free sugar are high in older infants and young children living in Europe. These findings are relevant taking into account the specific nutrient needs during these early stages of life, supporting the optimal development of organs and their function. Possible longterm consequences of these nutrient gaps could affect the development of a healthy taste and eating habits as well as the body composition.

For this review, we were dependent on the available dietary intake data across Europe. Several European countries, such as Norway, Portugal, and Switzerland, lack national data on infants' and children's food and nutrient intakes and surveys are often out of date: 8 out of 13 dietary surveys are more than 5 years old. Moreover, the methodologies of the different dietary surveys differ from country to country and are therefore difficult to compare.

For example, dietary surveys differed in age categories, dietary assessment methodology, sample size, and definitions of nutrients. Some surveys were limited to a specific geographical area or population and were not necessarily representative of the entire country. For example, the Belgian survey was done in Flanders, Belgium, only.

In order to obtain a clear overview of the nutritional reality of young European children, high-quality, representative food and nutrient intake data are needed. Dietary surveys should be performed on a regular basis in each European country to follow longitudinal trends in food and nutrient intakes.

Disclosure Statement

All authors are full time employees of Danone Nutricia Early Life Nutrition.

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IRON INTAKE AND STATUS OF CHILDREN AGED 6-36 MONTH IN EUROPE: A SYSTEMATIC REVIEW.

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Abstract

Background: Iron deficiency is the most common nutritional disorder in the world. Young children are particularly vulnerable to the consequences of iron deficiency because of their rapidly developing brain. This review evaluates the prevalence of inadequate iron intake and iron deficiency (anaemia) in European children aged 6–36 months.

Summary: Computerized searches for relevant articles were performed in November 2013. A total of 7,297 citations were screened and 44 studies conducted in 19 European countries were included in this review. In both infants (6–12 months) and young children (12–36 months), the mean value of iron intakes in most countries was close to the RDA. Nevertheless, proportions of inadequate intakes were considerable, ranging from about 10% in the Netherlands up to 50% in Austria, Finland and the United Kingdom. The prevalence of iron deficiency varied between studies and was influenced by children's characteristics. Two to 25% of infants aged 6–12 months were found to be iron deficient, with a higher prevalence in those who were socially vulnerable and those who were drinking cow's milk as a main type of drink in their first year of life. In children aged 12–36 months, prevalence rates of iron deficiency varied between 3 and 48%. Prevalence of iron deficiency anaemia in both age groups was high in Eastern Europe, as high as 50%, whereas the prevalence in Western Europe was generally below 5%.

Key Messages: In most European countries, mean iron intakes of infants and children aged 6 to 36 months were found to be close to the RDA. Nevertheless, high proportions of inadequate intakes and high prevalence rates of iron deficiency were observed. Health programs should (keep) focus(ing) on iron malnutrition by educating parents on food choices for their children with iron-rich and iron-fortified foods, and encourage iron supplementation programmes where iron intakes are the lowest.

Introduction

Iron is a mineral that is required for many metabolic processes to take place in the human body. Most importantly, it is part of haemoglobin and therefore essential for the delivery of oxygen to the cells in our body. Iron is also a structural component of many enzymes needed for a wide range of metabolic processes, such as phagocyte antimicrobial activity, neurotransmitter synthesis and function, and the production of DNA, collagen and bile acids [1]. The majority of iron required by the body is acquired from the reutilization of iron released from erythrocyte catabolism [2]. However, considerable amounts of iron must be provided by the diet to replace the iron that is lost from the body (through blood loss and exfoliation of skin and gastrointestinal cells) and the iron that is required for growth [1]. Healthy, full-term, normal birth weight infants are born with sufficient stores of iron to cover their needs during the first 4–6 months of life [3, 4] . After the age of 6 month, infants' iron reserves are depleted and the child becomes critically dependent on dietary iron [1, 3–5]. Since daily iron requirements (in mg/kg) are higher during late infancy and early childhood than during any other period of life [6], and many young children do not consume large quantities of iron-rich foods such as red meat and green leafy vegetables, young children are especially at risk of inadequate intakes of iron [7]. Inadequate dietary intakes of iron may lead to a depletion of body's iron stores or iron deficiency (ID) that, if not reversed, may progress to iron deficiency anaemia (IDA). ID and IDA are the most severe and prevalent nutritional deficiencies in the world, affecting both developing as well as industrialized countries [8]. Increasing evidence suggests that ID, with or without anaemia, may have a longterm detrimental influence on mental and psychomotor development [9, 10]. The less efficient supply of oxygen to the brain and the decreased brain energy production, together with the effects of iron deficiency on myelination and neurotransmitter function, are considered to be the most important mechanisms explaining the association between iron deficiency and impaired neuro-development [11, 12]. Young children are particularly vulnerable to the effects of iron deficiency because the first three years of life is a period of rapid growth and development of the brain and nervous system [13]. Especially in developing countries, it is well known that iron deficiency remains the most common nutritional deficiency in the world. In developed countries, among others Europe, the situation is less clearcut. Although many studies have evaluated iron intake and status among infants and young children in Europe, to our knowledge, no systematic review of published literature has been conducted. Therefore, we aimed to review the prevalence of inadequate iron intake and the prevalence of iron deficiency (anaemia) in European children aged 6 to 36 months.

Literature Search Strategy

Computerized searches for relevant articles were performed in Pubmed, Medline, CAB Health and Embase electronic databases in November 2013 using Medical Subject Heading (MeSH) terms or text words iron* , ferrous, ferric, ferritin, anemi*, hemoglobin or haemoglobin combined to intake*, diet*, supplement*, status, deplet*, deficien* , concentration* or level* and infan*, toddler* , baby, babies, child * or preschool* (truncated words are followed by an asterisk). Literature searches were limited to articles published after January 2000 in order to retrieve the most up-to-date figures. No language restriction were applied. Only studies in healthy, term-born children were included, thus excluding children particularly vulnerable to iron deficiency, such as premature infants, low birth weight infants and children with intestinal failure. Subjects from all socio-economic classes and ethnicity, as well as with different dietary habits were included. Baseline iron intake or status data of children enrolled in randomised controlled trials were not considered, because of potential selection bias due to exclusion criteria (e.g., baseline haemoglobin levels or breastfeeding habits) that were applied. In addition to the computerised literature search, the reference lists of the retrieved papers were searched for other relevant articles. Moreover, we used data gathered by a data collection tool developed by Nutricia Research. This tool is used to describe the nutritional situation of target population groups within a country and consists of two complementary approaches: (1) an extensive literature review covering both scientific published literature, as well as gray literature obtained from Governmental agencies and National and International organizations involved in food, nutrition and public health issues, and (2) interviews with key opinion leaders (mainly paediatricians) and scientific experts in the field of diet and nutrition [14]. In the past two years, nutrient intake and status of infants and young children has been assessed by this tool in six European countries (Austria, France, Germany, Italy, Portugal, and Switzerland). In the following sections we will first provide an overview of young children's iron requirement and recommended iron intake. Subsequently, mean intake data are compared to the Estimated Average Requirement (EAR) to estimate the prevalence of inadequate iron intake following the approach of the EURopean micronutrient RECommendations Aligned (EURRECA) Network of Excellence [15] . In short, the EAR cut-point is calculated as follows: z= (x-μ) / SD, where x is the EAR, μ the mean iron intake and SD the standard deviation, assuming a normal distribution. The estimated proportion of cases with inadequate iron intake is found by calculating the area under the normal distribution curve with mean = 0 and SD = 1 to the left of the z value. Similarly to a recent study of ILSI Europe [16], the EARs for comparison were obtained from the dietary reference values for Food Energy and Nutrients for the United Kingdom [17] . Although these values were set in 1991, there is little evidence to suggest that they have changed from that time to the present [16]. Finally, studies assessing the prevalence of ID and IDA are summarized and discussed.

Iron Requirement and Recommended Iron Intake

Physiological requirements for absorbed iron are based on estimates of the sum of basal iron losses, body iron accretion for growth and iron needed to maintain minimal iron stores to ensure normal function. Basal losses of iron are attributed to losses of iron in the faeces, urine, sweat and via exfoliation of epithelial cells, largely from the gastrointestinal tract [18, 19]. This physiological requirement is multiplied by an average figure for the absorption and bioavailability of iron from a typical diet to estimate the EAR, defined as the daily intake level of dietary iron sufficient to meet the needs of 50% of healthy individuals in a particular age and gender group. The RDA is the amount that will meet the daily requirement of almost all (97.5%) individuals and can be calculated by adding

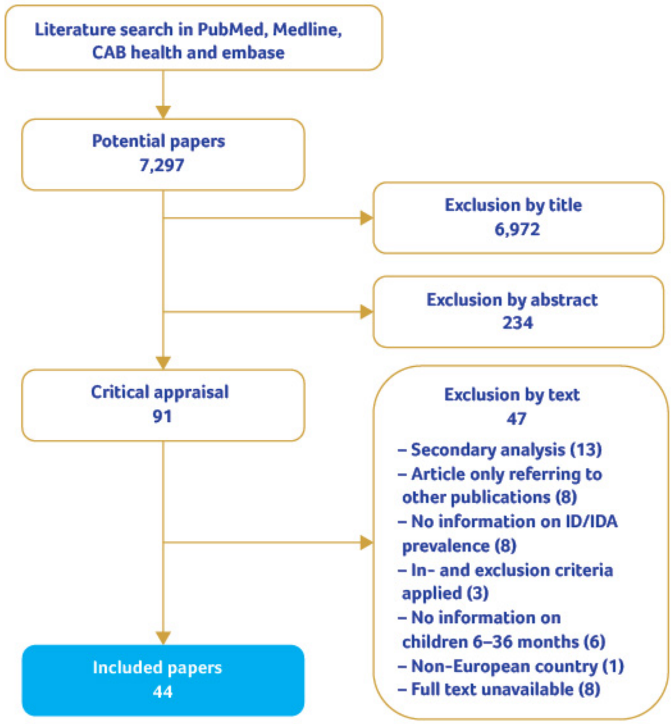

Fig. 1. *Literature search and selection.*

two standard deviations to the EAR value. Various institutions and organizations have given widely varying estimates for physiological iron requirements and the bioavailability of dietary iron [20] , and hence large variations exist among iron recommendations in different countries [21] . In Europe alone, RDAs of iron for children aged 1–3 years vary between 4 and 15 mg/day [22] . Most European countries, including France, Germany, Italy, Spain, the Netherlands and the United Kingdom, recommend a daily iron intake of 7 or 8 mg/day for children 6–36 months old [22] . The UK EARs that were used to assess the prevalence of inadequate intake in the current review were 6mg/day for 6-12 month old infants and 5.3 mg/day for 12-36 months olds [23] (UK RDA for 6–12 months and 12–36 months olds is 7.8 and 6.9 mg/day, respectively).

Literature Search Results

The initial literature search yielded 7,297 articles (fig. 1). A first screening based on the title and abstract identified 91 eligible articles that were retained for full-text review. This included both articles that were found by the computerized search of the electronic databases and by the Nutricia Research data collection tool. The data collection tool was especially useful to find publications in local language, data from National dietary surveys and grey literature. Thirteen manuscripts of these 91 studies published subgroup or further analyses as separate manuscripts and were excluded from further review to eliminate duplicate results. Moreover, three manuscripts were excluded because of in- and/or exclusion criteria that were applied. Additionally, studies were excluded if they did not report on: original data (e.g., reviews, opinion articles, letters to the editor; n = 8), prevalence of ID or IDA (e.g., studies that reported only average haemoglobin levels or only the prevalence of anaemia; n = 8), healthy children between 6 and

Table 1. *Mean iron intake in children aged 6–36 months and the prevalence of children having an intake below the Estimated Average Requirement (EAR) in Europe*

Country [ref.]	Representative[a]	Intake method	Year[b]	Age, months	n (M/F)		Mean iron intake mg /day	SD	% below EAR
Austria [33]	Yes	3 × 24 h	2006	12–36	183 (83/100)		5.3	2.9	50.0
Belgium[d, f] [34]	No	7 days duplicate	1999 - 2000	24-47	115		7.8	2.0	59.9
Belgium[d] [35]	No	3 days DR	2002-2003	30-48	197 (102/95)	boys	7.7	2.2	13.8
						girls	7.1	2.1	19.6
France[d, g] [27]	Yes	3 days WDR	2005	6	58 (36/22)		8.6	2.7	-
				7	66 (35/31)		8.9	2.9	15.9
				8-9	67 (36/31)		8.7	2.7	15.9
				10-12	63 (41/22)		7.4	3.0	32.0
				13-18	66 (36/30)		7.4	2.5	20.0
				19-24	66 (35/31)		6.6	3.2	34.8
				25-30	65 (31/34)		6.5	2.7	32.8
				31-36	62 (31/31)		6.6	2.2	27.7
Finland[e] [36, 37]	Yes	3 days DR	2003-2004	12-23	455[g] (257/198)	boys	6.7	2.3	27.1
						girls	6.2	2.9	37.8
				12-23	112[j] (55/57)	boys	5.2	2.1	51.9
						girls	4.7	1.7	63.8
				24-35	230 (112/118)	boys	6.0	2.5	39.0
						girls	5.7	1.9	41.7
Germany[d] [38]	Yes	3 days WDR	1985-1989	12-47	105		5.6	2.1[1]	10.9
Germany[d] [39]	Yes	3 days WDR	1986-2000	24-47	916		5.8	1.6	4.0
Germany[d,g] [25]	Yes	2 x 3 days WDR	2001-2002	6-11	157 (83/74)	boys	6.1	3.0	48.7
						girls	6.1	4.4	49.1
				12-23	168 (81/87)	boys	5.9	2.8	41.5
						girls	5.8	3.1	43.6
				24-35	174 (89/85)	boys	6.7	3.2	33.1
						girls	6.0	2.6	39.4
Netherlands[e] [40]	Yes	2 days DR	2005-2006	24-35	640 (327/313)	boys	6.6	1.6[1]	20.2
						girls	6.4	1.8[1]	26.8
Netherlands[e] [30]	Yes	2 days DR	2002	9	333 (164/169)		9.5	2.3	6.4
				12	306 (158/148)		8.5	3.4	23.1
				18	302 (156/146)		6.3	2.5	34.5
Iceland[e] [24]	Yes	3 days WDR	2005-2006	9[i]	122	boys	6.3	3.2	46.3
						girls	6.3	2.7	45.6
				12	110	boys	6.8	4.0	42.1
						girls	5.8	2.0	54.0
Ireland[e] [41]	Yes	3 days DR	2012	12-23	126		7.0	3.0	28.6
				24-35	124		7.6	3.2	23.6
Poland[e] [42]	?	24 h	2000	12-47	118 (70/48)	boys	5.4		
						girls	4.9		
Poland[e,g] [28]	Yes	24 h	2006[c]	6	43		9.7	2.8	-
				12	56		7.7	2.9	27.9
Poland[e] [43]	Yes	3 days DR	2010	13-36	400 (222/178)		8.5	3.0	14.3
Spain [44]	Yes	FFQ + 24 h	1998 - 2000	24-60	367 (192/175)	boys	10.3[k]		
						girls	9.0[k]		
Spain [31]	No	FFQ + 24 h	2000[c]	7-12	75 (43/32)		11.5	4.8	12.6
Sweden [29]	No	5 days DR	2003	12	82	boys	9.1	2.7	12.6
						girls	8.8	2.4	12.2
UK[d] [45, 46]	Yes	3 days DR	1994 - 1996	18[i]	1,026 (563/463)	boys	5.5	2.0	46.0
						girls	5.2	1.7	52.4
				43	863 (488/375)	boys	6.4	1.7	25.9
						girls	6.0	1.9	34.4
UK[d,h] [26, 91]	Yes	4 days WDR	2001 - 2003	6[i]	50 (25/25)		6.9	2.8[l]	-
				12	50 (27/23)		5.2	2.5[l]	62.5
UK[e] [47]	Yes	4 days DR	2008 - 2010	18-47	219 (117/102)		6.4	2.5	33.3
UK[d] [32]	?	7 days WDR	1996 - 1998	4	152		5.0	3.3[m]	-
				8	155		8.4	3.8	26.4
				12	150		7.2	3.8	37.6
				16	143		5.4	2.2	48.2
				20	135		5.1	1.9	54.2
				24	130		5.3	2.0	50.0

M = Male; F = female; EAR = estimated average requirement; 24 h = 24 hour recall; duplicate = duplicate sample method; DR = dietary record; WDR = weighted dietary record. [a] Representative Sample of the population of the country under study (assessed by original authors). [b] Year of food intake assessment. [c] Year of publication. Year of food intakes assessment not reported. [d] Intake only from food. [e] Intake from foods and supplements. [f] Participating children were recruited from hospitals. All had a normal eating pattern and none of the children had metabolic or gastrointestinal disorders. [g] Only non-breastfed infants. [h] Validation study that compared dietary intake from a food-frequency questionnaire with a 4-day weighed dairy. Only the results of the 4-day weighed dairy are presented as this method was considered the gold standard.[i] Children followed longitudinally over time. [j] Partially breastfed infants. [k] Standard deviation was not available from the publication and subsequently the percentage of children below the EAR could not be calculated. [l] Mean and standard deviation were not available from the median and percentiles (using the methods described by Hozo et al. [92]). [m] Mean values and pooled standard deviations were calculated from mean and standard deviation in subgrups.

36 months (n=6), and if they were conducted in a non-European country (n = 1). Finally, we excluded papers for which we were unable to obtain the full text (n = 8), ultimately resulting in 44 studies included in this review (fig. 1).

Iron Intake

Most of the studies assessing iron intake were carried out in a population-based sample representative of infants and young children in the entire country (table1). Table 1 summarizes the average intakes and presents the prevalence of inadequate intake of iron. In infants aged 6–12 months old, average iron intakes were close to the RDA of 7.8 mg/day in most European countries for which data were available (fig. 2a). Intakes were found to be lower in Iceland (5.8–6.8 mg/day) [24] , in Germany (6.1 mg/day) [25] and in one study performed in the United Kingdom (5.2 mg/day) [26]. The prevalence of inadequate intake ranges between 15 and 30% in 6 to 12 month old infants from France [27], Poland [28] and Sweden [29], while the prevalence of inadequate intake was 6% in 9 month old infants from the Netherlands [30] and 13% in 7–12 month old infants from Spain [31]. Infants from Germany and Iceland had a prevalence of inadequacy around 50%, while prevalence of inadequacy in infants in the United Kingdom varied between 25 and 60% depend-ing on the study [26, 32] .

For children aged 12–36 months, average iron intakes in many countries were slightly below the RDA of 6.9 mg/day (table 1; fig. 2b) [25, 27, 30, 32–47] . France, Ireland, the Netherlands, Poland and Spain showed a prevalence of inadequancy below or around 30%, whereas higher inadequancy levels (up to 60%) were found in Austria, Belgium, Germany, Finland and the United Kingdom.

Iron Status

In contrast to the studies assessing iron intake, the majority of studies assessing iron status were conducted in one centre, one city or a specific part of the country, not necessarily representative for the entire country (table 1). In most studies, ID was defined as a serum ferritin (SF) level below 12 µg/l as proposed by the World Health Organization (WHO) [8]. Yet, cut-off values of 10 and 16 µg/l as proposed by the World Health Organization (WHO) [8] . Yet, cut-off values of 10 and 16 µg/l have also been used (table 2). IDA is generally defined as ID in combination with a haemoglobin (Hb) level below 110 g/l. When different cut-off values were described in a paper, the cut-off value for Hb and SF as established by the WHO were used wherever possible.

Prevalence of Iron Deficiency

Twenty-two studies reported on ID prevalence estimates [24, 32, 48–67], of which 15 studies showed results for infants (6–12 months of age) [24, 32, 48–52, 55, 57, 59–61, 63, 64, 67] . In infants, prevalence rates of ID strongly depend on a family's socioeconomic status. Twenty-six percent of 10-month old French infants coming from socially vulnerable families were found to be iron deficient, compared to 10% of infants not at risk for socioeconomic deprivation [50]. Besides the socioeconomic status, the infant's current or past type of milk consumption was also an important determinant of ID. Polat et al. showed that 3–4% of 6-month-old infants who were currently fed human milk or formula feeding were iron deficient, compared to 25% of infants who were receiving cow's milk [51]. In 8 to 12 month old infants, ID was found in 5–12% of currently human milk fed infants, 7–15% of currently cow's milk fed infants, and 2–4% of infants consuming formula milk [59, 61]. Moreover, in a study in which infants were stratified according to their predominant milk intake (human milk or infant formula) during the first 4 months of life, ID was found in approximately 5% of 4-month old infants, irrespective of the type of milk feeding. At 7 and 10 months of age, around 20% of infants who had been fully breastfed for 4 months were iron deficient compared to none of those receiving infant formula [55] . These results were at least partly explained by the low iron intake throughout the complementary feeding period in formerly fully breast-fed infants. In Iceland, the prevalence of ID decreased from 41 to 6% after the publication of revised dietary guidelines, in which (partial) breast feeding was encouraged until 1-year old and iron-fortified formula was rec-ommended instead of regular cow's milk as the main substitute for human milk in the second half of the first year [24, 57]. Studies not differentiating between socio-economic status or type of milk consumption reported prevalence rates of ID between 4 and 18% in 6–12 month old infants in various countries [32, 48, 49, 52, 60, 63, 64]. Also in the older age category (>12 months), prevalence rates were dependent on the type of milk consumption. Vincelet et al. categorized 16 to 18 month old children into groups based on their current milk consumption and found that ID was present in 27, 44–59 and 85% of children who predominantly consumed formula milk, cow's milk and human milk, respectively [54]. In the Netherlands, the use of formula and the visit of preschool/day care were associated with a lower prevalence of ID [67] . Among children aged 1 to 3 years, 13% of children who received formula were iron deficient, whereas among children not receiving formula, 30.5% were iron deficient. The intake of >400 ml of cow's milk per day occurred significantly and more frequently in children with ID than in those without ID [67]. Other studies including children conducted in Albania [53], Greece [56], Iceland [58] and the United Kingdom [62] found similar prevalence rates of ID from 27 to 48%. However, three other studies per-formed in 13 to 24 month old children from the United Kingdom reported ID prevalence rates of only 3 to 8%, using similar or even stricter definitions of ID [32, 65, 66].

Prevalence of Iron Deficiency Anaemia

The reported prevalence of IDA in infants and young children was below 5% in countries in Northern and Western Europe (i.e., Denmark [48], Germany [55], Iceland [24, 57, 58] , Norway [60] and the United Kingdom [62, 65]) and in Spain [64] , with the exception of one study conducted in Dutch children 6 months to 3 years that detected IDA in 8.5% of the children [67]. Reported prevalence rates were considerably higher in Eastern European countries. In Estonia [49], Greece [56] and in two studies performed in Turkey [52, 68], the prevalence of IDA was 9 to 16%, and estimated prevalence rates reached up to 50% in Albania [53] and in cow's milk-fed infants in Turkey

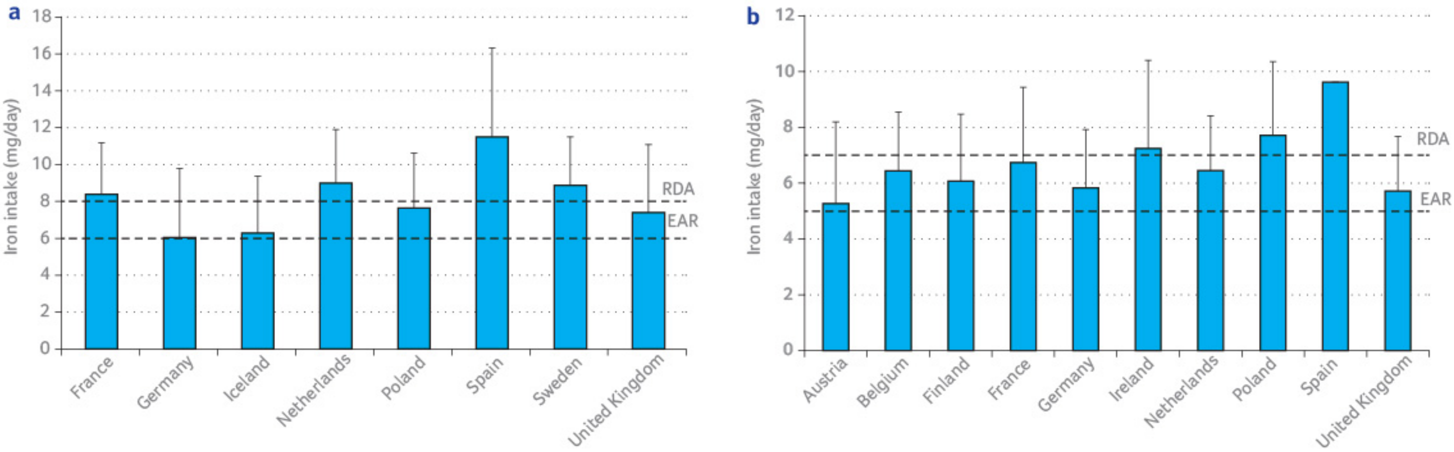

Fig.2. *Average iron intakes (mg/day) in infants aged 6–12 months* **(a)** *) and young children aged 12–36 months* **(b)** *) in differ-ent European countries, compared to the estimated average requirement (EAR) and the recommended dietary allowance (RDA). The error bars represent the pooled standard deviation of the included studies (see table 1).*

[51] (table 2). In the EURO-Growth study, a study in which IDA was assessed among 12-month-old infants in 11 European areas (Athens, Bilbao, Budapest, Dublin, Madrid, Naples, Porto, Rostock, Santiago, Umeå and Vienna) [63], IDA prevalence was on average 2.3% and ranged from 0 to 12% between study centres.

Table 2. *The prevalence of children aged 6–36 months with Iron Deficiency Anaemia (IDA) and Iron Deficiency (ID) in Europe*

Country [ref.]	Representative[a]	Year[b]	Age, months	n	Subgroup	Iron deficiency anaemia		Iron deficiency	
						prevalence, %	criteria Hb, g/l; SF, µg/l	prevalence, %	criteria SF, µg/l
Albania [53]	No	2000	6-60	112		42	110;10[i]	48	10
Denmark [48]	No	2008-2009	9	278		0.7	100;12	7.8	12
Estonia [49]	Yes	2004-2005	9-12	171		9	105;12[j]	14	12
France [54]	No	2002	16-12	13	BF[e]			85	12
				178	SCM			59	12
				23	WCM			44	12
				323	FM			27	12
France [50]	No	1998	10	304	Socially vulnerable[f]			26	12
				463	At risk of vulnerability			16	12
				1.142	Standard			10	12
Germany [55]	No	2005-2006	4[d]	53	BF (0-4 months)[g]	0	105;12	6	12
				23	IF (0-4 months)	0	105;12	4	12
			7	53	BF (0-4 months)	4	105;12	19	12
				23	IF (0-4 months)	0	105;12	0	12
			10	53	BF (0-4 months)	2	105;12	21	12
				23	IF (0-4 months)	0	105;12	0	12
Greece [56]	No	2007[c]	8-24	369		16	110;10	34	10
Iceland [57]	Yes	2003[c]	12	114		2.7	105;12[j]	41	12
Iceland [58]	Yes	2004[c]	24-30	71		1.4	105;12[j]	27	12
Iceland [24]	Yes	2006[c]	12	138		0	105;12[j]	6	12
Italy [59]	?	2000-2005	8[d]	102	BF			12	15
				63	FM			15	15
				220	FM			4	15
			12	70	BF			8	15
				72	CM			11	15
				160	FM			3	15
Netherlands [67]	No	2011-2012	6-36	400		8.5	110;12	19	12
Norway [60]	No	1997	6[d]	278		2	110;12	4	12
			12	249		5	110;12	10	12
			24	229		5	110;12	13	12
Spain [64]		2002[c]	12	94		4.3		9.6	
Sweden [29]	No	2003	12	87				10	12

Table 2 (Continued)

Country [ref.]	Representative[a]	Year[b]	Age, months	n	Subgroup	Iron deficiency anaemia prevalence, %	Iron deficiency anaemia criteria Hb, g/l; SF, µg/l	Iron deficiency prevalence, %	Iron deficiency criteria SF, µg/l
Turkey [68]	No	2002[c]	12-71	84		16	105;16		
Turkey [51]	No	2002-2006	6	240	BF (exclusive)	5.4	110;12	4.2	12
				195	FM/BF	8.7	110;12	3.1	12
				177	CM/BF	53	110;12	25	12
Turkey [52]	No	2007[c]	7	256		9.0	110;10	14	10
UK [62]	Yes	1992-2003	18-54	727		3.4	110;10	31	12
UK [61]	Yes	1993-2004	8[d]	113	BF[h]			5	16
				126	CM			7	16
				687	FM			2	16
			12	102	BF[h]			5	16
				105	CM			11	16
				574	FM			3	16
UK [65]	Yes	1994	18	709		1.7	110;12	4	12

Hb = Haemoglobin; SF = serum ferritin; BF = breast fed; CM = cow's milk; FM = formula milk.
[a] Representative sample of the population of the country under study (assessed by original authors). [b] Year of iron status assessment. [c] Year of publication. Year of iron level measurement not reported. [d] Children followed longitudinally over time. [e] BF, children, who were currently receiving human milk; SCM, children who were currently receiving semi-skimmed cow's milk; WCM, children who were currently receiving whole cow's milk; FM, children who were currently receiving iron-fortified formula milk. [f] Based on family income estimation and status. [g] BF, children who were predominantly breastfed for the first 4 months of life; IF, children who were predominantly iron-fortified infant formula fed for the first 4 months of life. [h] BF children who received human milk (with or without some cow's milk but no formula) at 8 months of age; CM, children who received only cow's milk at 8 months of age; FM, children who received iron-fortified formula milk (with or without some human and/or cow's milk) at 8 months of age. [i] SF <10µg/l or the combination of mean cell volume <70 fl and red cell distribution width >14.5%. [j] Plus mean cell volumen <74 fl. [k] Hb <110 g/l plus two or more abnormal iron indicators out of four (SF <10 µg/l, MCV <70 fl, transferrin saturation <10%, serum transferrin receptor concentration >4.4 mg/l).

Discussion

Iron Intake

In most European countries, the mean iron intakes of infants and children aged 6–36 months were found to be close to the RDA. Nevertheless, high proportions of inadequate intakes were observed among both age categories, that is, up to 50% in infants between 6–12 months and up to 60% in children between 12 and 36 months (table 1). These data ilustrate that a mean intake above the RDA does not necessarily reflect a low prevalence of inadequacy. The evaluation of the dietary reference values for iron is complicated by the fact that the distribution of iron requirements is asymmetrical [69] . This is reflected in the great variety of reference values that have been proposed for iron by different authorities. Similarly to a recent study of ILSI Europe [16] , we used the EARs set by the UK Committee on Medical Aspects of Food Policy [17] . The fact that a very high proportion (up to 50% of 6–12 month olds and up to 60% of 12–36 month olds) have inadequate iron intakes while only a smaller proportion of children have ID (up to 25% of 6–12 month olds and up to 48% of 12–36 month olds), leads us to the question whether the requirements have been estimated too high. Although the RDA proposed by the UK Committee on Medical Aspects of Food Policy is similar to the one proposed by the US Institute of Medicine [19] (6.9 mg/day vs. 7 mg/day), the EAR is markedly higher (5.3 mg/day vs. 3 mg/day). European alignment of reference values for infants and young children based on the latest scientific data is urgently needed.

Large differences were observed in the prevalence of inadequate intake between and within countries, depending on differences in age and gender of the studied children, and on country-specific factors, such as the voluntary or mandatory iron fortification of flour and breakfast cereals, and the use of follow-on or young-child formula fortified with iron. For example, the use of iron-fortified breakfast cereals have been shown to be positively associated with iron intake in infants and young children in France, Ireland, United Kingdom and Spain [70, 71] . Moreover, various methods for assessing iron intake have been used in different countries, for example, some surveys used a single 24-h recall to measure iron intake, whereas others used a 3- or 7-day (weighted) dietary recorde (table 1).

As this review is based on published studies, we did not have access to the raw data and therefore, all estimated prevalence rates for inadequate intake are based on published values (mean and standard deviation). Subsequently, the presented estimates are less accurate than would have been the case if raw data had been available. Yet, in a study for which we had raw data [43] , there was only a small difference between the estimated percentage of children with iron intakes below the RDA using published data (14.3%) and the percentage calculated using the raw data (12.5%). Another limitation was that in the studies in our review no information was available on the form of iron (haem or non-haem iron) or the presence of inhibitors and enhancers of iron absorption in the diet, which are important factors in determining the bioavailability of iron.

Iron Deficiency

When comparing the prevalence of ID between the studies, large variations in study results were observed. This is, at least partly, due to the problem that no consensus exists on the criteria for the diagnosis of ID and in different studies different cut-off values were used to define ID. For example, a number of studies used the stricter cut-off level for SF of 10 µg/l [32, 52, 53, 56, 63, 66] to define iron deficiency (vs. only two studies that used a higher cut-off level [59, 61]). Nevertheless the results confirm that ID is common in countries in Europe (table 2). The prevalence rates probably would even be a few percent-ages higher if the SF >12 µg/l cut-off would have been applied in all studies. Two to 25% of infants aged 6–12 months were found to be iron deficient, with a higher prevalence in infants who were socially vulnerable and infants consuming cow's milk as a main drink in their first year of life. In children of 12–36 months, the reported prevalence rates of ID varied between 3 and 48%. These huge variations are most likely explained by the age of the children under study, the year of study performance and country differences as in the social economic status, ethnicity and the use of iron-rich or fortified complimentary foods and drinks. Several studies found a positive association between (red) meat, fruit and vegetable intake and iron status in young children [24, 62, 65, 72], and a recent meta-analysis in 2–5 year old children showed clear effects of iron supplementation on Hb and SF response [73]. Also differences in the use of foods that have a negative impact on iron status, such as dairy products (containing calcium), high-fibre foods (containing phytates) and tea and coffee (containing polyphenols) may contribute to variations between countries in the prevalence of ID [74]. Of the studies performed in the United Kingdom, the only study with a very high prevalence of ID (31%) was conducted in 1992–1993. These were the years that the bovine spongiform encephalopathy (BSE) crisis reached its peak in the United Kingdom and the consumption of beef, an important source of iron, fell by 25% [75]. However, although the iron intake of young children has improved with an increase in mean intake from 4.9 mg/day in 1992–1993 [76] to 6.4 mg/day in 2008–2010 [47], iron intake is still lower than the recommended amount and 33% of children has an intake below the EAR.

Iron Deficiency Anaemia

Similar to the ID prevalence rates, the reported prevalence rates for IDA varies greatly between countries and between studies. IDA prevalence was generally below 5% in Northern and Western European countries, whereas it reached 50% in some countries and populations in Eastern Europe (table 2). The higher prevalence of IDA in Eastern Europe can at least partly be explained by the fact that in many, especially rural parts of Eastern Europe, cow's milk is an important part of the diet of infants below 1 year of age, and iron-fortified milk and cereals are not often consumed in this age group [77]. Moreover, other conditions presenting with low SF and Hb levels such as β-thalassemia syndromes, are much more common in these regions than in the Western and Northern parts of Europe. For example, the reported prevalence of haemoglobinopathy gene carriers is 7–10% in Turkey, compared to only 0.5–1% in Germany [78]. Although the prevalence of IDA is relatively low in large parts of Europe, iron deficiency in infants and young children is still a public health priority as children with depleted iron stores but without anaemia at 1 year of age might have lower fine motor and mental development scores in later childhood than children with sufficient iron stores [10, 79–83]. On the other hand, it has been suggested that supplemental iron in infants with high Hb levels may adversely affect neurodevelopmental outcome [84]. Defining optimal amounts of iron in iron-fortified milk and foods is therefore of upper most importance.

A number of studies included in our review confirmed that the consumption of cow's milk in the infant and child diet is an important predictor of iron status [54, 60]. The low iron content in cow's milk is likely the most important cause of this association [85]. Thane et al. reported that children consuming more than 400 ml of milk (all types) per day, which is recommended in this age group to ensure a sufficient supply of calcium and B-vitamins, were less likely to consume iron-rich complementary foods, like meat, fish, fruit and nuts, and these children were more at risk to have a poor iron status [62]. Moreover, cow's milk is rich in calcium and casein, both known to inhibit iron absorption [85]. Other studies showed that late weaning, and particularly the late introduction of iron-rich meat, is an important predictor of iron deficiency in children older than 1 year [86, 87].

Conclusions and Areas for Further Research

In conclusion, we showed that mean iron intakes of infants and children aged 6 to 36 months in most European countries are close to the RDA. Nevertheless, high proportions of inadequate intakes and high prevalence rates of ID were observed. IDA is especially common in Eastern Europe where up to half of the children are affected, while the prevalence in Western and Northern Europe is generally below 5%.

Several European countries, such as Norway, Portugal and Switzerland, lack national data on infants' and children's iron intake, although these data are needed to determine compliance with daily recommended iron levels and to assess the risk of inadequate intake. Moreover, surveys are often out of date, data are not always collected using the preferred method [88] and there is a scarcity of data on national prevalence of ID and IDA in infants and children; many studies that reported on the prevalence of ID or IDA focused on limited geographical areas that are not necessarily representative of the entire country.

Further research should focus on accurately establishing iron requirements in young children and identifying the components in a young child's diet that are especially contributing to (high) iron intakes and an appropriate iron status. Sophisticated analytical methods should be applied to associate the effects of iron intake (haem and non-haem iron) and contributing dietary factors with iron status. Insight in these components of the diet of children younger than 36 months may contribute to improved dietary guidelines for these children ensuring adequate amounts of iron in the diet and body stores. Moreover, the relationship between maternal ID/IDA and their infants' iron status and development warrants further study. Several studies have demonstrated that effects of pregnant women's iron status on infant iron status are more apparent in later infancy than in the newborn period [89, 90].

Health programs should (keep) focus(ing) on iron malnutrition by educating parents on food choices for their children with iron rich and iron fortified foods, and where iron intakes are lowest, encourage iron supplementation programmes.

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SNACKING FOR A CAUSE: NUTRITIONAL INSUFFICIENCIES AND EXCESSES OF U.S. CHILDREN, A CRITICAL REVIEW OF FOOD CONSUMPTION PATTERNS AND MACRONUTRIENT AND MICRONUTRIENT INTAKE OF U.S. CHILDREN

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Abstract
The objective of this review was to identify dietary insufficiencies and excesses in children aged two to 11 in the United States (U.S.) and eating habits that merit concern in terms of nutrient and energy density to improve overall diet quality. Data from the What We Eat in America (WWEIA) tables from the National Health and Nutrition Examination Survey (NHANES) were examined as well as survey data from the School Nutrition Dietary Assessment Study (SNDA). Analysis of survey data revealed that children consume insufficient Vitamin D, calcium, and potassium and excess energy, carbohydrates, and sodium. Dietary modifications are necessary to prevent serious deficiencies and the development of chronic illness. Snacking has steadily increased in this population since the 1970s, and snacks provide necessary nutrients. However, carbohydrates and added sugars tend to be overconsumed at snacking occasions. Replacement of current snack choices with nutrient-dense foods could lower the risks of nutrient deficiencies and help lower excess nutrient consumption. Increased consumption of low sugar dairy foods, especially yogurt, at snack times could increase intake of important micronutrients without contributing to dietary excesses.

1. Introduction
The United States (U.S.) has the third highest healthcare expenditure in the world [1]. In 2010, over 17% of the U.S. gross domestic product was spent on healthcare [2]. Preventative care measures, including dietary improvements, could help reduce these costs over time, especially through encouraging health-promoting practices for children. Over 30% of U.S. children and adolescents are overweight or obese [3], which increases their risk of becoming overweight or obese adults [4]. However, even though they consume excess energy, American children consume insufficient nutrients.

The National Health and Nutrition Examination Survey (NHANES) evaluates the health and diet of the U.S. population. NHANES data show that children aged two to 11 have low overall intakes of fiber, Vitamin D, calcium, and potassium, but an excess consumption of added sugars and refined carbohydrates, in addition to energy. Too little Vitamin D, calcium, and potassium can lead to a wide range of health problems later in life, including osteoporosis, hyperparathyroidism [5] and hypertension [6]. Energy and refined carbohydrate-laden diets can also lead to an increased susceptibility to becoming overweight or obese and to developing cardiovascular disease [7,8]. Furthermore, nutrient-poor diets consumed during childhood can establish a lifetime pattern of poor eating habits [9].

To improve the health of the U.S. population, it is vital to address the nutrition of its children and promote positive change in children's eating choices. The 2010 Dietary Guidelines for Americans (DGA) provide the official nutrition recommendations for Americans two years of age and older and include information on how to structure a health-promoting diet. The 2010 DGAidentify potassium, dietary fiber, calcium, and Vitamin D as "nutrients of concern" across the population [9]. The intake levels of these nutrients are low enough across the population to be a concern for public health [9]; data from the 2009–2010 NHANES also show low intake levels of these four nutrients among children aged two to 11 [10] (the only exception to the low levels of nutrients was calcium consumption for two to five year olds, which slightly exceededtherecommended-Dietary Reference Intake). In conjunction with the "nutrients of concern," the 2010 DGA include a list of foods Americans should consume more frequently [9]. This list includes a variety of fruits and vegetables, whole grains, low fat milk and milk products, seafood and other lean protein options, and oils [9]. Vegetables, fruits, dairy products, and whole grains are all mentioned as good food sources for the nutrients of concern [9]. In addition to nutrients of concern and foods to eat more of, the 2010 DGA list food components to reduce, which include sodium, saturated fat, trans fat, cholesterol, added sugar, solid fat, and refined grains [9].

MyPlate, the visual representation of the 2010 DGA, is another source for U.S. dietary recommendations. The MyPlate graphic is a plate divided into sections by food group (vegetables, fruits, grains, protein foods, and dairy) [11]. The size of each section on the plate depicts how much of each food group should be consumed daily. For example, vegetables and grains are the largest two sections on the plate, reflecting recommendations that Americans consume more vegetables and more whole grains [11]. MyPlate also encourages Americans to be physically active and to avoid dietary sources of solid fats, added sugars, and excess sodium [11]. In addition to providing information regarding the overall daily intakes of each food group, NHANES data also include information on when children tend to consume different nutrients. Encouraging changes to the nutrient profile of different eating occasions is one possible method of improving children's eating habits.

2. Data Sources

The dietary data used for this analysis come primarily from the What We Eat in America (WWEIA) tables of the 2009–2010 NHANES and School Nutrition Dietary Assessment Study (SNDA) data. NHANES is an annual survey of American children and adults conducted by the Centers for Disease Control and Prevention, the United States Department of Agriculture (USDA), and the National Center for Health Statistics to study the health of the national population, including its dietary habits. WWEIA data are cross-sectional data based on two days of 24-h dietary recall. The NHANES data used originates from the WWEIA tables available on the USDA website and from published scientific articles. Publications used include Centers for Disease Control and Prevention and USDA publications as well as articles found via keyword searches on government institution websites and scientific databases such as PubMed and Science Direct. NHANES 2009–2010 data was the source of information for children's breakfast, lunch, snack, and dinner consumption habits.

Information on children's lunches also comes from the SNDA, which evaluates the nutritional quality of meals offered to school-aged children and adolescents through the National School Lunch Program (NSLP) and the impact of this program on children's health. The USDA's Food and Nutrition Service contracted with Mathematica Policy Research to conduct the SNDA-IV [12]. The SNDA has been administered periodically since 1991 [13]. Data from SNDA-III (2004–2005) and SNDA-IV (2009–2010) were used in this publication. SNDA data were used in conjunction with NHANES data for lunch consumption information because many elementary school students (63%) participate in the NSLP [13]. The NSLP follows recommendations outlined in the 1995 School Meals Initiative for Healthy Children (SMI). SMI recommendations are based on Recommended Daily Allowances and the DGA [13]. SMI identifies "target nutrients" for school lunches, including protein, vitamin A, vitamin C, calcium, and iron [13]. The SNDA distinguishes between foods "offered"versus foods "served" at school lunches.

Foods offered accounts for all options available for students to choose. Foods served includes the foods that students select or are given for lunch. Food consumption and macro- and micronutrient intake of children aged two to 11 from WWEIA tables and the SNDA-IV were compared with existing dietary recommendations to determine inconsistencies between recommendation and practice. Macronutrients studied include energy, carbohydrates, protein, sugar, fiber, and fat. Micronutrients studied include calcium, vitamin D, vitamin B12, magnesium, sodium, and potassium. NHANES data, SNDA-IVdata, data from scientific publications, and recommendation data was reformatted into tables and graphs using Microsoft Excel.

Dietary recommendations were taken from the USDA publications of the 2010 DGA and choosemyplate.gov website as well as from publications from the Institute of Medicine (IOM) for vitamin D and calcium intake recommendations. The 2010 DGA are largely based on 2005–2006 NHANES data and theIOM's Dietary Reference Intakes.

WWEIA information is listed in tables on the USDA website showing the relative percentage and amount of each nutrient consumed. These data are organized by gender, age group, and ethnicity. Energy contributions of each eating occasion (breakfast, lunch, snacks, and dinner) as well as nutrient consumption at each eating occasion are also available on the website.

For children aged two to five (n= 861) [10], a parent or caregiver completed the dietary recall information. For children aged six to 11 (n= 1132) [10], a parent or caregiver assisted the child with completion of the dietary intake questions.

School lunch data from the SNDA-IV is available online in summary reports. NSLP data from 902 schools, including 316 elementary schools, was collected for the SNDA-IV [12]. Schools across the country were selected for the survey to produce nationally representative data. Data was collected both from School Food Authorities (SFA), or school district groups, and from groupings of SFAs and schools [12]. All public SFAs that participated in the NSLP were considered for participation in the SNDA-IV [12]. SFAs and schools were selected via two sample frames [12]. A sample of SFAs was chosen first [12]. Then, from a second sample of additional SFAs, individual schools were selected for the study based on location, income level, urbanicity, number of students, and SFA size [12]. Two surveys were administered, one to the SFA-only sample and a second survey for the SFA plus schools sample. A total of 595 SFAs were recruited for the study. Five hundred and seventy-eight SFAs completed SFA-level Director Survey [12].

3. Children's Food Intake by Meal

Our results represent information from the primary data sets listed above. Food intake data in children is limited, and the data sets used for our analysis are considered the best information available on eating habits and nutrient intakes of children in the U.S. Self-report data have limitations, but for these surveys, attempts were made to obtain the best information possible. For example, preschool children are not able to describe their food intake accurately, so parents or caregivers completed the dietary recalls for children aged 2–5 years.

Furthermore, different surveys use different cut-offpoints for data analysis. Since our information was obtained from published papers and government reports, we were unable to correct for different age ranges. We always point out the age range used in the data set we are quoting.

NHANES surveyed children aged 2–11 years and grouped them into "younger"(ages 2–5) and "older" (ages 6–11) categories. Some reports such as DGA list individuals up to 13 years of ageas children and split the children into three groups by age range. Different studies may also include different exclusion criteria, but the goal of these surveys is to obtain a representative sample of American children.

Breakfast: Most children consume at least one food for breakfast, and foods eaten at breakfast provide important micronutrients, especially Vitamin D and calcium [14]. NHANES data shows that breakfast provides 34%–39% of children's Vitamin D intake and 25%to 28% of their calcium intake [14]. Overall, breakfast contributes to 30%–35% of total daily key vitamin and mineral intake (with "key vitamins and minerals" defined as Vitamin D, B12, calcium, sodium, potassium, and magnesium) [14].

Snacks: Ninety-seven percent of the children surveyed eat a snack, and half of these children eat multiple snacks per day [15]. Snacks contribute to 37% of children's energy intake [16] but only provide15%–30% of vital micronutrients [17]. Popular snack choices include desserts and sugar-sweetened drinks [16], and snacks consist of almost 40% of the added sugar in children's diets [17]. Overall, children aged two to five consume 12 teaspoons of sugar per day, and children aged six to 11 consume about 18 teaspoons of sugar per day [10].

Lunch: SNDA data shows that the average school lunch comes within 10% of the SMI's standards for its target nutrients [18]. NSLP lunches also generally provided at least one third of the recommended daily amounts of grains, dairy foods, and oil, but they are also high in calories from solid fats and added sugars [13].

According to NHANES data, most children (93%) aged two to five eat lunch, and lunch provides about 25% of their daily energy intake [19]. Lunch accounts for 23% of the consumption of nutrientsof concern for these children and also contributes to 20% of their sugar intake [19].

Dinner: Most children consume at least one food item for dinner, an eating occasion that provides 21%–28% of calcium intake and about 20% of Vitamin D, 30% of potassium, and 30% of the dietary fiber consumed by children aged two to 11 [20]. Dinner foods also comprise about 20% of children's sugar intake [20].

4. Children's Overall Nutrient Intake

Most American children consume snacks, but most of the snacks consumed are energy-rich and nutrient-poor choices, especially considering that children already consume excess energy and insufficient nutrients. Although snacking itself can be an important habit for weight maintenance [21],replacing current snack foods with health-promoting options, especially options naturally abundant in nutrients of concern, would improve children's diet quality [22].

Certain nutrients of concern, notably calcium and Vitamin D, are sometimes consumed as supplements, however, the Food and Drug Administration, the Academy of Nutrition and Dietetics, and the 2010 DGA recommend consuming foods for adequate nutrition instead of supplements [9]. Based on this recommendation, improving children's nutrient intake would be best accomplished through changing food consumption habits rather than encouraging supplement usage or reliance. Children already receive most of their calcium and potassium intake from food instead of supplements; more than 97% of calcium consumed by children comes from food alone [23] and almost 100% of children's potassium intake [23] comes from food.

Yogurt, fruits, and vegetables are naturally rich sources of the 2010 DGA's nutrients of concern and are also foods that children do not consume sufficiently (Table 1) [9]. Adding one 6 oz serving of yogurt each day would help children move closer to DGA recommendations for almost all of the nutrients of concern [24]; combining yogurt and fruit or yogurt and vegetables for snacks would increase consumption of all of the nutrients of concern. According to the USDA's National Nutrient Database for Standard Reference, a typical serving of Vitamin D fortified, fruit-flavored, low fat yogurt is about 6 oz and contains 235 mg calcium, 301 mg potassium, 2.2 µg Vitamin D, and 31 g sugar [25]. Adding one daily serving of yogurt as a snack for children ages nine to 11 would provide enough calcium for this group to meet recommended intake levels (Table 2), and a serving of yogurt would increase Vitamin D and potassium consumption for children in all age groups. Children of all age groups do not consume enough of those two nutrients (Table 2).

Table 1. *NHANES Food Groups: Recommended Intake versus Actual Consumption, Comparisons using Recommendation Information from Choosemyplate.gov and Consumption Data from 2009–2010 NHANES data for Children 2–11 Years Old.*

Food Group [26]	Recommended Daily Intake [11]	Actual Intake [26]
Dairy foods	2–3 years old (both genders): 2 c 4–8 years old (both genders): 2.5 c 9–13 years old (both genders): 3 c	2–5 years (females): 2.46 c 2–5 years (males): 2.31 c 6–11 years (females): 2.03 c 6–11 years (males): 2.46 c
Fruits	2–3 years old (both genders): 1 c 4–8 years old (both genders): 1–1.5 c 9–13 years old (females): 1.5 c 9–13 years old (males): 1.5 c	2– 5 years (females): 1.43 c 2–5 years (males): 1.49 c 6–11 years (females): 1.20 c 6–11 years (males): 1.03 c
Protein foods	2–3 years old (both genders): 2 oz 4–8 years old (both genders): 4 oz 9–13 years old (females): 5 oz 9–13 years old (males): 5 oz	2–5 years (females): 2.93 oz 2–5 years (males): 3.05 oz 6–11 years (females): 3.59 oz 6–11 years (males): 3.97 oz
Vegetables:	2–3 years old (both genders): 1 c 4–8 years old (both genders): 1.5 c 9–13 years old (females): 2 c 9–13 years old (males): 2.5 c	2–5 years (females): 0.69 c 2–5 years (males): 0.66 c 6–11 years (females): 0.80 c 6–11 years (males): 0.78 c
Total Grains: refined and whole grains	2–3 years old (both genders): 3 oz 4–8 years old (both genders): 5 oz 9–13 years old (females): 5 oz 9–13 years old (males): 6 oz	2–5 years (females): 4.54 oz 2–5 years (males): 4.92 oz 6–11 years (females): 6.73 oz 6–11 years (males): 6.75 oz
Whole Grains	2–3 years old (both genders): 1.5 oz 3–8 years old (both genders): 2.5 oz 9–13 years old (females): 3 oz 9–13 years old (males): 3 oz	2–5 years (females): 0.61 oz 2–5 years (males): 0.79 oz 6–11 years (females): 0.61 oz 6–11 years (males): 0.65 oz

Table 2. *2010 DGA Nutrients of Concern: Recommended Intake versus Actual ConsumptionComparisons using Dietary Reference Intakes or Adequate Intake and 2009–2010 NHANES data for Children 2–11 Years Old.*

Nutrient of Concern	Recommended Daily Consumption	Actual Daily Intake (from Food)
Vitamin D	1–3 years old (both genders) [27]: 10 µg 4–8 years old (both genders) [27]: 10 µg 9–13 years old (both genders) [27]: 10 µg	2–5 years old (both genders) [23]: 6.8 µg 6–11 years old (both genders) [23]: 6.1 µg
Potassium	1–3 years old (both genders) [27]: 3000 mg 4–8 years old (both genders) [27]: 3800 mg 9–13 years old (both genders) [27]: 4500 mg	2–5 years old (both genders) [23]: 2071 mg 6–11 years old (both genders) [23]: 2172 mg
Calcium	1–3 years old (both genders) [27]: 700 mg 4–8 years old (both genders) [27]: 1000 mg 9–13 years old (both genders) [27]: 1300 mg	2–5 years old [23]: 1032 mg 6–11 years old (both genders) [23]: 1048 mg
Dietary fiber	1–3 years old (both genders) [27]: 19 g 4–8 years old (both genders) [27]: 25 g 9–13 years old (females) [27]: 26 g 9–13 years old (males) [27]: 31 g	2–5 years old (females) [10]:11.3 g 2–5 years old (males) [10]:12.1 g 6–11 years old (females) [10]: 14.5 g 6–11 years old (males) [10]: 13.6 g

Yogurt manufacturers are already working to decrease the amount of added sugars in yogurt. The amount of added sugars listed by the USDA's National Nutrient Database for Standard Reference [25],referenced above, does not reflect the amount of added sugars in some yogurt brands. For 6 oz of low fat strawberry yogurt, one national brand contained 21 g of sugar and another national brand contained 24 g, while some yogurt marketed to children can have as few as 18 g of sugar, according to company websites. The amount of sugar in these products is much lower than the amount listed in the USDA's database. However, not all yogurts on the market have reduced sugar content, and many products still do not meet the IOM's standard for competitive foods in schools. Although removing all added sugars would likely discourage consumption, especially among children, establishing the IOM's 23 g of total sugar per 6 oz serving as a recommended maximum amount would allow for a decrease in added sugars without removing them completely.

Finally, the proposed Nutrition Facts labels would decrease the serving size, or Reference Amounts Customarily Consumed, of yogurt from 8 oz to 6 oz [28], a more common size for single-serving yogurt containers [28]. This serving size reduction would allow low fat yogurt to contain 3 g of fat per 6 oz of yogurt instead of 3 g of fat per 8 oz serving. Recent studies suggest that dairy fat and full-fat dairy products confer health benefits that low fat or nonfat dairy products do not [29–31]. Choosing a whole milk yogurt instead of a nonfat yogurt may also decrease the need for added sugars to increase palatability, as the fat in yogurt provides flavor and increases satiety. In comparison to a 6 oz serving of fruit-flavored yogurt, 6 oz of plain whole milk yogurt contains a total of 8 g of sugar with amounts of vitamin D (if fortified), calcium, and potassium comparable to that of a low fat, flavored yogurt [25]. Increasing acceptability and availability of whole milk yogurts with low sugar content may be a beneficial way to encourage health-promoting and nutrient-dense snacking among children without raising sugar consumption.

5. Limitations of the Review

Using different sources for intake and recommendation information created some limitations to the scope and analysis of this review. As shown in Tables 1 and 2, data sources for nutritional intake and recommendation information use different age ranges, which complicates comparisons. NHANES, for example, separates data about children into "two to five years old" and "six to 11 years old" categories, while the 2010 DGA has three categories for children: one to three years old, four to eight years old, and nine to 13 years old.

In addition, because data for lunch consumption in this paper comes from NHANES data for children ages five years of age and younger and from school lunch intake data (SNDA-IV) for children ages six and older, and different data are collected for each survey, developing a comprehensive overview of children's lunch consumption habits was not feasible. For example, the SNDA does not collect data on all of the DGA's nutrients of concern, including Vitamin D and potassium. This difference may be a cause for concern because it prohibits the development of a complete overview of the nutrient consumption of children while at school and complicates finding and addressing the most prevalent areas of concern in children's diets.

School lunch data presents an additional complicating factor, because SNDA data reflect the meals that children were offered or served but not consumption data. While children may be offered or served certain foods, data on food consumption is not collected. A recent study on school lunch waste indicated that the measure of food served was not an adequate representation of food consumptionat school lunch [32].

Finally, when the data analysis for this review was conducted, only raw data from the 2009–2010 NHANES were available. Analyzeddata from the 20092–010 NHANES were not yet available.

6. Conclusions

American children aged two to 11 consume extra energy and sugars in their diets but insufficient Vitamin D, calcium, and potassium. One way to address the insufficiencies and excesses of children's diets would be to change the nutrient density of children's snacks. Foods high in added sugars and energy currently dominate children's snack choices. Substituting one serving of low sugar, whole milk yogurt, paired with fruit or vegetables, for current snacks would increase children's consumption of valuable nutrients without adding excess sugar or energy.

Author Contributions

Hess analyzed the data and wrote the first draft of the manuscript. Slavin helped design the review, assisted in data analysis, and reviewed and approved the final manuscript.

Conflicts of Interest

The authors declare no conflict of interest.

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Snacking for a Cause: Nutritional Insufficiencies and Excesses of U.S. Children, a Critical Review of Food Consumption Patterns and Macronutrient and Micronutrient Intake of U.S. Children

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DIETARY INTAKE BY DUTCH 1- TO 3-YEAR-OLD CHILDREN AT CHILDCARE AND AT HOME

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Abstract
The goal of the current study was to assess dietary intake in a large sample (N = 1016) of Dutch toddlers (1–3 years old), both at childcare and at home. Dietary intake during two weekdays was recorded using an observation format applied by childcare staff for intake at childcare, and partially pre-coded dietary journals filled out by parents for intake at home. Children's intake of energy, macronutrients and energy balance-related food groups (fruit, vegetables, sweet snacks, savoury snacks) were compared with Dutch dietary guidelines. In addition, differences between the dietary intake by various subgroups (based on gender, age, childcare attendance, socio-economic status of childcare centre) were explored using multilevel regression analyses, adjusting for nesting of children within centres. Energy intake was high relative to dietary guidelines, and children consumed more or less equal amounts of energy at home and at childcare. Dietary fibre, fruit and vegetable and snack intakes were low. Intake at childcare mainly consisted of carbohydrates, while intake at home contained more proteins and fat. The findings imply various opportunities for childcare centres to improve children's dietary intake, such as providing fruit and vegetables at snacking moments. In addition, the findings underline the importance of assessing dietary intake over a whole day, both at childcare and at home, to allow intake to be compared with dietary guidelines.

1. Introduction
Worldwide, at least 42 million children under the age of five were overweight in 2010, and these numbers are expected to continue to increase [1]. Childhood overweight is a major risk factor for several chronic conditions such as cardiovascular diseases and type 2 diabetes mellitus [2]. Moreover, childhood overweight is known to track into adulthood, in that overweight children often remain overweight or obese during later life [3]. Dietary intake plays a crucial role in the development of overweight [4]. Dietary habits are often established at a young age [5] and maintained throughout life [6–8], indicating the urgency of increasing our understanding of the origin and development of dietary habits in young children. In Europe, over half of the toddlers (below primary school age) attend some form of childcare or educational facilities [9]. It has been recommended that a child in full-time childcare (i.e., 8 h or more per day) should consume one half to two-thirds of his or her daily dietary intake at childcare [10], indicating the importance of childcare for the development of children's dietary habits. Childcare use has been found to be associated with an increased overweight risk throughout childhood (e.g., [11–13]). Furthermore, various studies have shown that children attending childcare often do not meet dietary intake recommendations: they may consume excess energy [14] and excessive amounts of total fat [14,15], saturated fat [15,16] and sweets [14]. In addition, they are not consuming sufficient amounts of fruit [16], vegetables [14,16,17] and dietary fibre [18]. However, several of these studies were limited to dietary intake at childcare [16,19,20], ignoring the intake at home. As such, they have to rely on the estimated proportion of the dietary intake that takes place at childcare. Since dietary intake at home is not known, these studies assume the composition of the meals to be stable throughout the day and do not take into account possible compensation behaviour at home. The studies that have taken account of both dietary intake at home and intake at childcare [14,15,17,18,21–23] mostly had small sample sizes (N < 200) [14,17,18,21,22], assessed dietary intake at childcare through the parents [18], or only examined specific meals instead of dietary intake during a whole day [18]. In addition, the majority of the studies examining dietary intake have been conducted in the United States [14–18,20,21], with only a few from Europe [19,22,23]. The current study aimed to assess dietary intake in terms of energy, macronutrients and the food groups of fruit, vegetables, sweet snacks and savoury snacks, both at childcare and at home, in a large sample (N = 1016) of Dutch toddlers (aged 1–3 years). In addition, it explored the dietary intake in various subgroups (according to gender, age, childcare attendance and socio-economic status (SES) of the childcare centre's neighbourhood).

2. Methods
2.1 Respondents and Procedure
Ethical approval for this study was not required according to Dutch law, since the current research did not involve invasive procedures, and thus did not fall under the Dutch Medical Research Involving Humans Act (Wet Medisch-Wetens chappelijk Onderzoek met Mensen) [24]. All childcare centres in the Netherlands were approached to participate in the study from March 2011 onwards. Several strategies were used to recruit childcare centres. A direct mailing of letters was sent to

addresses acquired by purchasing commercially available addresses. In addition, a digital mailing was sent, and childcare centers were recruited at conferences and through appointments at the head offices of the childcare organizations to which the centres belonged. If the head office was interested, the recruitment was continued at the individual centres. All childcare centres were allowed to participate. Sometimes a centre decided not to participate citing reasons such as that it would be too much effort, the centre had been closed down, the parent committee did not agree or management had changed. The 112 childcare centres that responded before August 2013 were included in the study. Data collection started as soon as a childcare centre consented to participate. All parents of the children aged 1 to 3 years from these centres were invited to participate. A total of 2788 children participated. All parents of participating children provided informed consent. Children's dietary intake was recorded on two entire weekdays, randomly chosen during one week, both at home using food diaries and at childcare using observations.

2.2 Assessment of Dietary Intake

In the Netherlands, children attending childcare usually consume their breakfast at home. Subsequently, they consume a morning snack, lunch and afternoon snack at childcare, and their dinner again at home.

2.2.1 Dietary Intake at Childcare

Staff at the childcare centre was instructed by a dietician to record the dietary intake of each of the participating children on a poster. The poster was a partially pre-coded dietary record, providing a list of the most common products that might consumed at each different eating moment. For instance, it showed a list of sweet snacks, beverages and fruits commonly consumed at snacking moments in the Netherlands. In addition, it provided space at each eating moment to record any other products consumed which were not on the standard list. There was a separate column on the poster for each participating child, where their intake could be recorded. Childcare staff was asked to specify the type of product (e.g., whether the milk product consumed was milk, chocolate milk, butter milk or yoghurt drink), the unit (e.g., whether it was a cup or a bottle), and the amount (i.e., number of units). The first eating moment (the snacking moment of the first observation day) was recorded together with the dietician, at which point the childcare staff received detailed instructions from the dietician on how to record the dietary intake. If the childcare staff were still uncertain about any aspects, these would also be explained by the dietician. During the rest of that day, and on the second observation day, the childcare staff filled in the poster for all eating moments at the centre (i.e., morning snack, lunch and afternoon snack). An additional questionnaire was filled in by the childcare staff together with the dietician to record further information regarding the meals and foods offered at the centre, such as the standard portion size used for certain products (e.g., how many mL were in the cups used) and the type and brand of particular products (e.g., whether regular or low-fat margarine was used and what brand).

2.2.2. Dietary Intake at Home

Parents were also asked to record their child's dietary intake at different eating moments at home during the two measurement days (i.e., breakfast, dinner including dessert, and anything consumed after dinner, including anything consumed during the night). The questionnaire consisted of a partially pre-coded food journal, providing a list of common products that might be consumed at each different eating moment. For instance, the food journal listed the bread and bread products, butters or margarines, sandwich toppings, fruit, porridges and beverages that are often consumed at breakfast in the Netherlands. In addition there was space to record any other products consumed at each eating moment that were not on the standard list. Parents were asked to specify the type of product (e.g., whether bread was white or brown), the unit (e.g., whether it was a slice of bread or a roll), the brand, and the amount (i.e., number of units).

2.3. Assessment of Background Characteristics

Children's age (rounded off to whole months), gender and the number of days they attended childcare were asked for in the parental questionnaire. The socio-economic status (SES) score of the population catered for by each childcare centre was derived from the centre's postal code. These SES scores are standardized scores per neighbourhood, reflecting educational level, income, and work status of the residents of that neighbourhood [25]. The SES scores were recoded into low, medium and high, based on tertile cuts of all scores in the Netherlands [25].

2.4. Processing of Dietary Intake Data

Only respondents for whom complete dietary intake data were available (for both measurement days, both at childcare and at home) were retained in the analyses. Of the 2788 children participating in the entire study, 1016 (43.7%) provided complete dietary intake data for both measurement days, both at home and at childcare. Of the 1773 children without complete data, the majority (75.0%) had complete data at childcare, but data at home was only available for 1 day or no days at all. Furthermore, 24.0% had only attended childcare on the day, so data for two complete days at childcare could not be provided, and 1.0% only provided data for intake at home, but not for childcare. The 1016 children with complete data were included in the final analyses. The observed and reported dietary intake data of the children were entered by the dieticians in the FoodFigures Program [26] separately for each of the six eating moments (breakfast, morning snack, lunch, afternoon snack, dinner, evening snack).

The amounts consumed as reported by the childcare staff and parents were recalculated by this program into weights and volumes using the procedures on measures and weights of the Dutch nutrient database [27] where necessary (e.g., using a standardized weight for a slice of bread). Amounts of half or a quarter of a portion were also recalculated by the program. As the focus of the current paper was on dietary intake, the average intake per day of the following nutrients was calculated by the program, based on the Dutch nutrient database [27]: energy (in kcal), proteins (in energy percent (en%)), carbohydrates (en%), total fat (en%), saturated fat (en%), unsaturated fat (en%) and fibre (grams (g)). In addition, intake from the following energy balance-related food groups was calculated: fruit (g), vegetables (g), sweet snacks (g; including sweets (e.g., jelly candy, liquorice, marshmallows), chocolate, cookies (e.g., butter cookies) and pastry (e.g., cake, pie)) and savoury snacks (g; including salty snacks (e.g., potato chips) and fried snacks (e.g., fried meats)).

2.5. Data Analyses

All analyses were conducted using SPSS 20.0 [28]. p-Values < 0.05 were considered statistically significant. Independent t-tests and chi-square tests were conducted to compare the background characteristics (children's age, gender, childcare attendance, and the childcare centre's SES) of the children in the final sample with those of children who had incomplete data and were thus excluded. Descriptive statistics were used to explore the children's background characteristics and total dietary intake. In addition, children's total dietary intake was compared with the dietary guidelines for toddlers from the Netherlands Nutrition Centre (Voedingscentrum; see Table 1) [29]. The overall dietary guidelines applied in the current study were specific Dutch guidelines [29]. The dietary guidelines for toddlers from the Netherlands Nutrition Centre refer to the guidelines for a healthy food choice of the Netherlands Nutrition Centre for a balanced dietary intake for children of one year and older. These guidelines are therefore used as a benchmark source for nutrient and food group analyses. Next, children's dietary intakes at home and at childcare were analysed separately, as well as their intakes at different eating moments (breakfast, morning snack, lunch, afternoon snack, dinner and evening snack).

Table 1. *Total dietary intake by toddlers, compared to national guidelines (= 1016).*

Dietary Intake	Actual Total Dietary Intake Mean (SD)	Dietary Guideline[a]	Percentage of Children Meeting the Guideline
Energy (kcal)	1285.1 (238.2)	1200	37.5% [b]
Carbohydrates (en%)	55.7 (5.2)	≥45	98.1%
Proteins (en%)	14.3 (2.1)	≥20	99.2%
Fat			
Total (en%)	30.0 (4.8)	25-40	83.2%[c]
Saturated (en%)	10.7 (1.8)	≤15	98.6%
Unsaturated (en%)	16.6 (3.7)	-	-
Dietary fibre (g)	12.5 (2.7)	≥15	17.2%
Fruit (g)	124.1 (61.9)	≥150	27.5%
Vegetables (g)	64.7 (36.5)	≥50-100	69.3%[d] 17.0%[6]
Sweet snacks [f] (g)	13.5 (12.0)	-	-
Savoury snacks [g] (g)	0.7 (4.0)	-	-

Notes: en% = energy percent, g = grams, mL = millilitres, N = number of children, SD = standard deviation; a Nutritional guidelines from the Netherlands Nutrition Centre ([29]). No specific guidelines are available for unsaturated fats and snacks; b 10% deviation from the guideline allowed (i.e., 1080–1320 kcal). Below the guideline: 18.8%; above the guideline: 43.7%; c below the guideline: 14.9%; above the guideline: 2.0%; d N (%) meeting the guideline of 50 g/day; e N (%) meeting the guideline of 100 g/day; f Including sweets, chocolate, cookies and pastry; g Including salty snacks and fried snacks.

In addition, the intakes by subgroups of children based on gender (boys vs. girls), age (2, 3 or 4 years old), childcare attendance (up to 2 days vs. 3 or more days a week) and the childcare centre's SES (low, medium or high) were explored. Multi-level linear regression analyses were conducted to examine the associations between these background variables and the dietary intake variables, corrected for the nesting of children within childcare centres and the background variables.

Results

Of the 1016 children, 54.8% (N = 554) were male. The average age was 2 years and 1 month (SD = 10 months), with 313 1-year-olds (34.1%), 330 2-year-olds (36.0%) and 274 3-year-olds (29.9%). On average, the children went to childcare for 2.4 days per week (SD = 0.6). A total of 24.5% of the children attended childcare centres that were located in low-SES neighbourhoods, 28.2% in medium-SES neighbourhoods, and 47.3% in high-SES neighbourhoods. Children included in the final sample attended childcare for slightly more days a week than children with incomplete dietary intake data (2.4 vs. 2.1, $p < 0.001$). There were no other significant differences in background characteristics (age, gender, childcare SES) between children who did or did not drop out.

3.1. Dietary Intake and Guideline Compliance

Table 1 lists the total dietary intake of the toddlers in the current study, as well as the number and percentage of children complying with the dietary guidelines of the Netherlands Nutrition Centre [29]. About one third of the children (37.5%) complied with the guidelines regarding energy intake. A smaller group (18.8%) consumed less than the recommended amount of energy, while most children (43.7%) consumed more energy than recommended. The vast majority of the children met the guidelines with regard to macronutrients (carbohydrates, proteins and fat). However, only 17.2% of the children consumed sufficient dietary fibre. This was also reflected in the low percentages of children consuming sufficient fruit and vegetables. Snack intake (both sweet and savoury) was generally low.

3.2. Dietary Intake at Childcare and at Home

Children consumed more or less equal amounts of energy at home and at childcare. However, while their intake at childcare mainly consisted of carbohydrates, a relatively larger proportion of the intake at home consisted of proteins and fat (see Table 2). Furthermore, children consumed most of their fruit at childcare, and most of their vegetables at home. Sweet snacks were mostly eaten at childcare.

3.3. Dietary Intake at Different Eating Moments

Table 3 shows the children's dietary intake at different eating moments, as well as the intake as a proportion of total daily intake (from different meals). The percentage of children consuming food at each of the eating moments was very high (98.6%–99.8%), except for evening snacks, which were consumed by only 62.8% of the children.

The main energy sources were lunch and dinner, together accounting for over half (57.4%) of the total energy intake. The snacking moments were very high in carbohydrates, while the main meals contained relatively larger proportions of proteins and fat. The main sources of dietary fibre were the main meals. Most fruit was consumed during the morning snacking moment, while the afternoon snacking moment often involved sweet snacks (e.g., cookies, sweets, pastry). The evening snacking moment involved a relatively large proportion of saturated fat compared to the other snacking moments.

3.4. Dietary Intake in Subgroups

Overall, there were few differences in total dietary intake between boys and girls. Boys consumed significantly more energy than girls (1304.8 vs. 1264.6 kcal, $p < 0.01$), as well as more dietary fibre (12.7 vs. 12.2 g, $p < 0.02$). There were no significant differences between boys and girls in intake specifically at childcare.

Intake of energy was significantly higher among older children, both specifically at childcare and for the day as a whole (see Table 4). Dietary fibre intake also increased with age, mainly at childcare. Sweet snacks intake increased with age, although at childcare, this increase was only significant between 2 and 3 years, while the increase in overall sweet snacks intake was only significant between 1 and 2 years. Total savoury snack intake increased between the ages of 1 and 2 years.

Children who attended childcare for 3 or more days a week had a higher total vegetables consumption (73.3 vs. 62.0 g, $p < 0.02$), and consumed more savoury snacks (1.1 vs. 0.6 g, $p < 0.04$; results not tabulated) than children attending childcare for 2 days or less. Childcare attendance was not significantly related to specific dietary intake at childcare.

Table 1. *Dietary intake by toddlers at childcare and at home (N = 1016).*

Dietary Intake	Dietary Intake Mean (SD)	
	At Childcare	At Home
Energy (kcal)	652.2 (169.9)	633.5 (171.9)
Carbohydrates (en%)	62.4 (6.6)	49.1 (8.4)
Proteins (en%)	12.0 (2.4)	16.8 (3.7)
Fat		
Total (en%)	25.6 (5.6)	34.1 (7.8)
Saturated (en%)	9.6 (2.3)	11.7 (2.8)
Unsaturated (en%)	6.6 (3.9)	19.5 (6.1)
Dietary fibre (g)	6.6 (1.8)	5.9 (2.1)
Fruit (g)	98.7 (46.0)	25.5 (41.4)
Vegetables (g)	10.9 (21.6)	53.8 (33.4)
Sweet snacks [a] (g)	10.3 (9.4)	3.3 (7.9)
Savoury snacks [b] (g)	0.2 (1.5)	0.5 (3.7)

Notes: en% = energy percent, g = grams, mL = millilitres; [a] Including sweets, chocolate, cookies and pastry; [b] Including salty snacks and fried snacks.

Table 3. *Dietary intake by toddlers at different eating moments.*

Dietary Intake	Dietary Intake Mean (SD)											
	Breakfast at Home (N = 1006)		Morning Snack at Childcare (N = 1010)		Lunch at Childcare (N = 1014)		Afternoon Snack at Childcare (N = 1002)		Dinner at Home (N = 1013)		Evening Snack at Home (N = 638)	
	Mean (SD)	% of total intake	Mean (SD)	% of Total Intake	Mean (SD)	% of Total Intake	Mean (SD)	% of Total Intake	Mean (SD)	% of Total Intake	Mean (SD)	% of Total Intake
Energy (kcal)	237.7 (87.1)	18.1	126.1 (51.8)	9.6	378.5 (122.9)	28.8	147.6 (67.9)	11.2	358.8 (120.0)	27.2	66.8 (63.5)	5.1
Carbohydrates (en%)	54.9 (10.6)	14.5	85.4 (10.8)	22.6	49.6 (7.7)	13.2	81.2 (12.8)	21.5	43.0 (11.6)	11.4	63.6 (23.1)	16.8
Proteins (en%)	15.0 (4.6)	19.6	5.2 (3.5)	6.8	16.2 (3.9)	21.3	6.4 (4.6)	8.4	19.1 (5.4)	25.1	14.3 (12.4)	18.8
Fat												
Total (en%)	30.0 (10.0)	20.5	9.5 (8.5)	6.5	34.5 (7.1)	23.5	12.5 (10.2)	8.5	37.9 (11.1)	25.9	22.1 (16.1)	15.1
Saturated (en%)	11.5 (4.2)	20.8	3.1 (4.6)	5.6	12.9 (3.1)	23.3	5.0 (5.4)	9.1	12.1 (3.6)	21.9	10.7 (8.9)	19.3
Unsaturated (en%)	15.7 (7.8)	20.8	4.1 (4.5)	5.4	18.3 (5.2)	24.2	5.5 (6.2)	7.3	22.7 (9.0)	30.0	9.3 (11.1)	12.3
Dietary fibre (g)	2.6 (1.2)	20.5	1.5 (0.9)	11.8	3.9 (1.4)	30.7	1.2 (0.9)	9.5	3.0 (1.3)	23.6	0.5 (0.9)	3.9
Fruit (g)	7.5 (22.6)	5.9	70.5 (51.7)	55.9	1.2 (8.6)	1.0	30.7 (45.0)	24.3	12.8 (27.6)	10.2	3.4 (14.2)	2.7
Vegetables (g)	0.3 (3.0)	0.5	0.1 (1.0)	0.2	5.1 (15.8)	7.8	2.8 (10.2)	4.3	56.4 (32.5)	87.0	0.1 (2.0)	0.2
Sweet snacks [a] (g)	1.2 (4.3)	8.7	3.6 (6.4)	26.1	0.2 (1.3)	1.4	7.3 (8.2)	52.9	0.8 (4.1)	5.8	0.7 (3.0)	5.1
Savoury snacks [b] (g)	0.0 (0.5)	0.0	0.0 (0.5)	0.0	0.0 (0.0)	0.0	0.3 (1.6)	42.9	0.4 (3.7)	57.1	0.0 (0.4)	0.0

Notes: en% = energy percentg = grams, mL = millilitres; [a] Including sweets, chocobte, cookies and pastry;[b] Including salty snacks and fried snacks.

Table 4. *Dietary intake differences based on age.*

Dietary Intake	Dietary Intake at children				Dietary Intake during a Whole Day			
	1-Year-Olds Mean (SD) N = 313	2-year-olds [a] Mean (SD) N = 330	3-Year-Olds Mean (SD) N = 274	Significance [b]	1-Year-Olds Mean (SD) N = 313	2-Year-Olds [a] Mean (SD) N = 330	3-Year-Olds Mean (SD) N = 274	Significance
Energy (kcal)	570.7 (150.1)	662.3 (158.2)	726.8 (170.9)	***	1165.9 (209.1)	1305.9 (210.1)	1400.4 (231.7)	***
Carbohydrates (en%)	62.5 (7.1)	63.0 (5.8)	62.3 (6.3)		55.7 (5.5)	56.0 (5.1)	55.8 (4.8)	
Proteins (en%)	12.1 (2.8)	11.8 (2.1)	12.0 (2.3)		14.5 (2.4)	14.1 (1.9)	14.2 (2.1)	
Fat								
Total (en%)	25.4 (5.8)	25.2 (5.2)	25.6 (5.3)		29.8 (5.1)	29.9 (4.7)	30.0 (4.4)	
Saturated (en%)	9.6 (2.4)	9.4 (2.1)	9.5 (2.1)		10.7 (1.9)	10.6 (1.7)	10.6 (1.6)	
Unsaturated (en%)	13.3 (4.0)	13.3 (3.8)	13.5 (3.7)		16.5 (3.9)	16.5 (3.5)	16.7 (3.5)	
Dietary fibre (g)	6.1 (1.7)	6.6 (1.9)	7.2 (1.8)	***	12.3 (2.6)	12.3 (2.6)	13.0 (2.7)	*c
Fruit (g)	99.8 (45.8)	98.4 (49.5)	98.9 (45.0)		122.6 (62.3)	124.3 (63.4)	127.8 (63.1)	
Vegetables (g)	13.5 (23.7)	9.8 (20.5)	9.8 (20.7)		68.5 (36.3)	61.9 (39.1)	64.6 (38.2)	
Sweet snacks [d] (g)	8.8 (8.3)	9.9 (8.6)	12.1 (11.4)	*e	11.3 (10.6)	13.6 (12.2)	16.0 (13.5)	*c
Savoury snacks [f] (g)	0.1 (1.3)	0.2 (1.5)	0.5 (1.9)		0.3 (1.9)	1.1 (5.8)	0.9 (3.5)	*c

Notes: en% = energy percent, g = grams, mL = millilitres; [a] Reference category; [b] Adjusted significance from multivariate multi-level regression analyses, adjusted for gender, childcare attendance and socioeconomic status score of the childcare centre; [c] Only significant for the 1-year-olds; d Including sweets, chocolate, cookies and pastry; e Only significant for the 3-year-olds; * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$; [f] Including salty snacks and fried snacks.

There were no differences in overall intake between childcare centres with different SES. With regard to the specific intake at childcare, children at high-SES childcare centres consumed significantly less fruit (93.0 g) than children at medium- and low-SES centres (106.2 g and 101.2 g, respectively, $p < 0.04$). On the other hand, they consumed significantly more vegetables at childcare (14.9 g) compared to children from medium- and low-SES centres (7.2 g and 7.3 g, respectively, $p < 0.01$). Children at low-SES childcare centres consumed significantly lower amounts of energy (619.0 kcal) than those at medium- and high-SES centres (679.8 and 652.9 kcal, respectively, $p < 0.04$). Finally, children at low-SES centres consumed significantly less savoury snacks (0.4 g compared to 0.1 g and 0.3 g in medium- and high-SES centres, respectively, $p < 0.05$; results not tabulated).

4. Discussion

The current study assessed dietary intake at childcare and at home in a large sample (N = 1016) of Dutch toddlers (1–3 years) who attended childcare. Energy intake was high relative to dietary guidelines, while dietary fibre, fruit and vegetable intakes were low. Snack intake (both sweet and savoury) was low. In 2005 and 2006, a national food consumption survey was conducted among toddlers in the Netherlands including children who attended childcare as well as those who did not. The dietary intake among the 2- to 3-year-olds (N = 788) from that survey was very similar to the intake we found in the current sample, specifically as regards the intake of energy, all macronutrients, dietary fibre and fruit (differences all <5%) [30]. This indicates that the overall dietary intake by children attending childcare does not seem to be very different from that by children not using childcare. Compared to the national survey, however, children in the current sample appeared to consume far less snacks (13.5 g of sweet snacks vs. 47 g in the national survey; and <1 g of savoury snacks vs. 3 g in the national survey) and more vegetables (64.7 g compared to 40 g in the national survey) [30].

It is unclear why there were such considerable differences with regard to vegetable and snack intakes, but not with regard to any other dietary intake measures. Perhaps the fact that the current study included 1-year-olds can partly explain these differences, especially with regard to snacks, because the 1-year-olds in the current sample consumed significantly less snacks than the older children. Furthermore, it should be noted that the current study did not include days on which the children did not attend childcare. It is possible that the children from the current sample had different intake patterns during a full day at home. However, a previous study by Ziegler and colleagues [18], which compared lunch and snacking moments at childcare with the corresponding eating moments during a full day at home, found only slight differences in intake between these two locations, which were only significant for the afternoon snacking moment: at home, children seemed to consume a bit more protein and fat in the afternoon. Furthermore, Ziegler et al. [18] reported more frequent consumption of salty snacks in the afternoon at home than at childcare. A study by Lehtisalo [23] that compared the dietary intake of children cared for at childcare with that of children cared for at home found lower vegetable consumption and higher sweet pastry consumption by the children cared for at home. These findings are in line with the deviating vegetable and snack consumption in the current sample compared to the national survey [30]. A final explanation for the differences between the current study and the national survey may regard the fact that the current study did not include weekend days. Several studies have shown that children's dietary intake is generally less healthy on weekend days (e.g., [22,23,31]), possibly explaining the lower snack consumption and higher vegetable intake in the current study.

In line with previous research among young children (e.g., [30,32]), the children in the current sample skipped very few meals and snacking moments: 98.6%–99.8% of the children consumed food at each of the eating moments (except for an evening snack, consumed by 62.4%). As regards the quality of children's diets, the macronutrient content of their diets seemed to be very good, with 83.2% to 99.2% of the children meeting the guidelines for carbohydrates, proteins, total fat and saturated fat. Studies from the US found excess consumption of total and saturated fat in childcare [14–16], perhaps reflecting a cultural difference between the US and the Netherlands. However, in line with previous US studies [14,16–18], many children in the current sample did not consume sufficient dietary fibre, vegetables and fruit. Furthermore, almost half of the children consumed excess amounts of energy (i.e., >1320 kcal), which is in line with previous research [14]. About equal amounts of energy were consumed at home and at childcare. Energy intake at the different eating moments in the current study was comparable to that found in US studies [18,20].

There were few differences in dietary intake between subgroups, both at childcare and in total. In line with previous research [19], boys consumed more energy than girls. In addition, boys consumed more dietary fibre. Concerns about children's diet seemed to change with age: while younger children were more likely to consume insufficient dietary fibre, the older children often consumed more snacks and energy. These differences were visible specifically at childcare as well as during a whole day, with the exception of savoury snack intake, whose increase was only significant as regards intake during a whole day. With regard to childcare attendance, children who attended three or more days a week consumed more vegetables and savoury snacks, though not at childcare, indicating that this increased vegetable and snack intake took place at home. Furthermore, we found older children to consume more energy, dietary fibre, sweets and snacks. Despite the fact that The Netherlands Nutrition Centre recommends the same intake for children aged 1–4 in their guidelines [29], our results show that children within this age group have different needs. Children in the age of 1 may for example still be nursed which influences their dietary intake.

Although the overall consumption of snacks seemed to be low (13.5 g of sweet snacks and less than one gram of savoury snacks per day on average), the majority of the sweet snacks were consumed at childcare, especially during the afternoon snacking moment. Fruit was consumed especially during the morning snack at childcare, and to a lesser extent in the afternoon. This indicates an opportunity for childcare centres to improve children's fruit consumption (which was too low for almost three quarters of the children), and at the same time even further lower snack consumption, by replacing the afternoon sweet snacks with fruit. Fruit consumption seemed to be especially low in high-SES childcare centres, while intake at home was not significantly different between childcare centres with different SES. Previous studies have repeatedly shown that children from low-SES families often consume less fruit (e.g., [33,34]). However, children from high-SES childcare centres in the current study also consumed more vegetables. It seems that high-SES childcare centres place more emphasis on vegetable intake, and less on fruit intake.

Various previous studies examining dietary intake at childcare have used the guidelines of the American Dietetic Association (that a child who spends a full day at childcare [i.e., 8 h or more] should consume one half to two-thirds of his or her daily dietary intake at childcare [10]) to convert daily dietary intake guidelines into estimated guidelines for intake at childcare (e.g., [16,17,19]). However, such conversion into childcare-specific guidelines ignores the fact that the composition of meals and other eating moments is not stable throughout a day (e.g., the composition of a typical lunch is different from the composition of a typical dinner), as the current study shows. It therefore makes no sense to apply the same guidelines at home and at childcare. This underlines the importance of studies assessing dietary intake during a total day, both at home and at childcare, enabling comparison with daily intake guidelines.

The current study had several limitations. There was a relatively high percentage of incomplete cases (56.3%), although the final sample included in the study can still be considered very large (over 1000 children from over 100 different childcare centres) compared to previous studies. This large sample size also provided sufficient statistical power to correct the analyses for the multi-level structure of the data. Nonetheless, there was some selective drop-out with regard to longer childcare attendance. In addition, the data collection took place over a relatively long period (30 months), which could have influenced the results. A strength of the current study was that dietary intake was assessed both at childcare and at home, making it possible to compare the intake with dietary guidelines without having to estimate the proportion of intake taking place at childcare. However, dietary intake at childcare was observed and recorded by childcare staff, while dietary intake at home was self-reported by parents, possibly introducing bias. Moreover, the dietary intake assessment methodologies used in both settings (childcare and home) were not validated, and weekend days were not assessed in the current study. With regards the software used to recalculate intake, participants were not asked whether children consumed their entire plate/glass which may have biased the reported intake. However, the ability of the program to register amounts of half or a quarter of a portion helped accurate assessment of children's intake. Moreover, the dietary intake in the current sample was very similar to the intake in a previous national survey, indicating that the assessment methods in the current study were probably sufficiently reliable.

5. Conclusions

In terms of energy balance, the main concern of children's dietary intake in our study was their low fibre, vegetable and fruit consumption, and their high energy intake, putting them at risk for developing overweight. Childcare has a large potential to contribute to resolving these issues, for instance by offering fruit as a snack twice instead of once a day, and by providing vegetables during lunch and snacking moments. This could potentially also further lower snack consumption and thereby lower energy intake, thus also reducing the overweight risk. Previous studies have shown that childcare staff can have an important positive influence on children's dietary intake at childcare, for example by serving sufficient healthy foods [16,35], preferably using a family serving style (in which the child can take healthy foods him/herself and can decide how much to take) [19,36,37] or indulgent feeding style (giving and offering seconds for healthy foods) [37,38]; by being a positive role model and eating healthy foods together with the children [19]; and by talking about healthy foods with the children [19]. As regards research, the current findings underline the importance of future research assessing dietary intake during a total day, both at home and at childcare. This enables comparison with daily guidelines, instead of having to convert these guidelines to improvised childcare-specific guidelines. In addition, intake should be assessed during a full day at home as well, including weekend days, to be able to compare intake at home and at childcare and to check for variability in children's diets across locations.

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Conflicts of Interest

The authors declare no conflict of interest.

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Dietary intake by dutch 1- to 3-year-old children at childcare and at home

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ANALYSIS OF NUTRITION OF CHILDREN AGED 13-36 MONTHS IN POLAND - A NATION-WIDE STUDY.

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Abstract
Aim: The aim of the study was to analyse the diets of children aged 13-36 months in Poland compared to nutritional recommendations. Material and methods: The questionnaire study was conducted between June and September 2010 on a representative, nation-wide sample of children aged 13-36 months. The study concerned 400 children from across Poland. They were selected by means of drawing their PESEL (personal identity) number. The nutritional status of children was assessed using anthropometric data, i.e. their current weight and height. The relative body mass index BMI (kg/m2) and the BMI z-score were calculated for each child and compared with the WHO child growth standards. The diets of children were assessed using an original questionnaire with 3-day diet records. Nutritional value was calculated using Dieta 4.0 computer programme. Results: The study demonstrated that 45.5% of children were in the normal BMI z-score range (from -1.0 to +1.0). Underweight children accounted for 12.5% (BMI z-score between -2.0 and -1.0) and severely underweight for 14.5% (BMI z-score < -2.0) of the studied group. The share of overweight and obese children was 14.5% and 13.0%, respectively. Large individual variation in food intake was observed in diets of the children. The intake of cereal products, meat, poultry and cold meats in daily diets was twice higher than recommended. The children ate significantly less vegetables and fruits and drank less milk and fermented milk beverages than recommended in model food rations. Energy and nutritional value of an average daily food ration di-ered considerably from the standards for majority of nutrients. The intake of proteins was three times higher than the current norms.

Conclusions: The diets of children aged 13-36 months di-ered from current recommendations but the nutritional status evaluated based on BMI was normal in 45.5% of children from the analysed group. The content of majority of macronutrients, in particular protein, in average daily food rations was incompliant with nutritional norms, which in long term may increase the risk of diet-related diseases. Current nutritional recommendations concerning the diets of children in the post-infancy period need to be verified and disseminated.

Introduccion
In 2007, the principles of nutrition for children aged 13-36 months were developed in Poland and were published in 2008 as a medical standard (1).

The recommendations were to highlight the importance of appropriate nutrition in small children in obesity and undernutrition prevention.

That year also saw the change in the previously binding nutritional standards (from 2001) for the Polish population (2, 3). The changes to nutritional standards were introduced due to the results of research in the field of nutrition sciences and concerned the energy and nutrient requirements. It has been demonstrated that the observance of nutritional standards by following the balanced diet combined with appropriate physical activity is linked to the reduced risk of diet-related diseases, including obesity (4, 5, 6, 7, 8, 9). Numerous studies have shown that the appropriate diet of children impacts their physical health and intellectual development (10, 11, 12, 13).

Until now, in Poland there has been no study involving comprehensive evaluation of the diets of children aged 1-3 years and performed on the representative sample. The results of isolated studies carried out in various centres on small groups do not allow to formulate any conclusions concerning the nutrition for children at this age (14, 15, 16, 17). The study carried out attempts at assessing the practical functioning of current recommendations for the diet of healthy children aged 13-36 months.

Objective
The objective of the study was to analyse the diets of children aged 13-36 months in Poland as compared to nutritional recommendations.

Material and Methods
The questionnaire survey was conducted between June and September 2010 on a representative nation-wide sample of children aged 13-36 months1. The study concerned 400 children from across Poland. The children were selected for the studied group by means of drawing the PESEL (personal identity) number. The inclusion criterion for the studied group was the age of children and the exclusion criterion were diseases requiring the modification of the diet. The nutritional status of children was measured using anthropometric data, i.e. their current weight (in kg) and their height (in cm) (from measurements made in an outpatient clinic, entered into the child medical record book), as well as the relative body mass index BMI (kg/m2) and the BMI z-score index (calculated on their basis, which were compared to the WHO child growth standards) (8, 18, 19). The diets of children were assessed using an original authors' questionnaire with the records on their 3-day diets. The questionnaires were filled in by mothers of selected children according to detailed instructions, with the

assistance of professionally prepared pollsters. According to the adopted methodology of nutritional studies, the records of the diets of children for subsequent three days, including one holiday, were used for calculating the average daily food ration (2, 20). The nutritional value was calculated using the Dieta 4.0 computer programme.

[1]Preliminary results - the final analysis is being prepared for the report of the study "Complex assessment of diets in children aged 13-36 months in Poland". Nutricia Foundation (No OPK 549-25-01).

Results

The studied group of children (n=400) consisted of 222 boys and 178 girls aged 1336 months. The average age of children was 1.96±0.57 years. From among the studied group, 79% of children lived in towns/cities, and 21% in the country. The children came from families where 34% of mothers had completed secondary education and 49% higher education, while the others (17%) had completed primary and vocational education. In the case of fathers, 34% of them had completed secondary education and 37% higher education, while the others (29%) had completed primary and vocational education. The percentage of mothers with completed secondary and higher education was higher than the percentage of fathers. Mothers of the studied children were better educated than fathers. Table I presents the characteristics of the studied group of children.

Anthropometric data such as current body mass and height of each child were used for calculating the body mass index (BMI) and compared with the standards (8, 18, 19). Table II presents the number of studied children in percentile ranges of the body mass index. The percentage of children with the BMI between the 25th and the 75th percentile was 33.2% and between the 15th and the 85th percentile – 47.0%. The percentage of children below the 15th percentile was 26.0% and above the 85th percentile – 27.0%. The nutritional status of children was assessed using the normalised BMI z-score calculated for each child. The study demonstrated that 45.5% of children were within the wide standard adopted for BMI from -1.0 to +1.0. The underweight children accounted for 12.5% of the studied group (BMI z-score between -2.0 and -1.0), and severely underweight for 14.5% (BMI z-score<- 2.0). Overweight and obese children accounted for 14.5% and 13.0%, respectively (fig. 1). The above data show that the nutritional status of 54.5% of the studied children was inappropriate, which requires a thorough analysis of the reasons for such irregularities, also in relation to the nutritional factor. The diets of the children assessed from the records of their 3-day diets, including the intake of various product groups, varied significantly, as demonstrated by large deviations from average values. After estimating 1200 diet records of the studied children (3-day diet records of 400 children) according to the adopted principles, the average daily food ration and its nutritional value were calculated (tab. III and IV). The intake of cereal products, meat, poultry and cured meats in daily diets of children was twice higher than recommended. e children ate significantly less vegetables and fruits, milk and fermented milk beverages than recommended in model food rations (tab. III) (21, 22, 23). Energy and nutritional value of an average daily food ration differed considerably from the standards for majority of nutrients (tab. IV). The intake of proteins was three times higher than the current norms. Similarly, the intake of vitamins A, B2, B6, B12, PP, C and intake of phosphorus, magnesium, zinc and copper in average daily food rations was two to three times higher than recommended. The protein intake provided 14.1±2.5% of total energy, fat – 28.9±5.2%, whereas carbohydrates accounted for 57.0±6.1% of total energy intake. Such a large share of protein and sucrose (14.3 vs the recommended 10%) were underweight and 27.5% overweight or obese. The diets of children aged 13-36 months varied in terms of their qualitative and quantitative composition. They were characterised by an excessive amount of high protein products and sucrose.

Discussion

The results of research conducted by different authors confirm significant correlations between the children's diets and their nutritional status (5, 9, 15, 24, 25, 26, 27, 28, 29, 30). There are publications indicating that eating behaviour develops in early childhood (31). Therefore, the appropriate diet not only promotes the optimal child development, but may also be one of the major factors reducing the risk of diet-related diseases in later life. -e results of isolated studies on the nutritional status and diet of children in the rst year of age, diet of children aged 1-18 years and a group of children aged 4 years, as well as the results of studies evaluating nutrition for infants and small children, are known in Poland (14, 16, 17, 32). The authors of the above studies have demonstrated adverse trends and practical dificulties in diversifying the children's diets, inappropriate choice of products in their diets, lack of balanced nutritional value of the diets, as well as the impact of the diet on nutritional status of children, including their overweight or underweight.

The studies conducted show that energy and nutritional value of the diets of children aged 13-36 months varied and was different than the current nutritional standards (developed in 2008), in particular for energy and protein, as well as vitamin A and vitamins from the B group. -e same results compared with the nutritional standards of 2001 clearly show that the diets of children in this age group were more balanced. The 2008 studies evaluating the diets of children (n=1692) attending Warsaw day care centres gave comparable results as at present, with regard to the earlier and the current nutritional standards (33).

The question is how to assess the obtained data, since the nutritional status of 45.5% of children shows that their diets are appropriate. The attempt of an answer to that question may be the verication of nutritional standards, in particular those concerning the amount of protein in the children's diets. The results concerning the intake of protein by children aged 13-36 months, obtained in the study on a representative, nation-wide group, may raise concerns, in particular when linked to the obesity prevention.

Conclusions

1. The diets of children aged 13-36 months differed from the current recommendations. However their nutritional status evaluated based on BMI raised no objections in 45.5% of children from the analysed group.
2. The content of the majority of macronutrients, in particular protein, in average daily food rations of the studied children was incompliant with nutritional standards, which in long term may cause the risk of diet-related diseases.
3. Current nutritional recommendations concerning the diets of children in the post-infancy period need to be verified and disseminated.

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NUTRITIONAL ADEQUACY OF DIETS CONTAINING GROWING UP MILKS OR UNFORTIFIED COW'S MILK IN IRISH CHILDREN (AGED 12 - 24 MONTHS).

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Keywords: Growing up milks · Toddler milks · Cow's milk · Iron · Vitamin D · Children

Abstract

Background: Growing up milks (GUM) are milk-based drinks with added vitamins and minerals intended for children aged 12-36 months. Few data are available on the consumption of GUM and their role in the diets of young children.

Objective: To determine the nutritional adequacy of two groups of 12-24-month-old Irish children by type of milk consumption (consumers or non-consumers of GUM)

Design: Using data from a cross-sectional study of Irish children, the National Pre-School Nutrition Survey (2010-2011), two groups of children were defined. The groups included children aged 12-24 months with an average daily total milk intake of at least 300 g and consuming GUM (]100g/day) together with cow's milk (n29) or cow's milk only (n56).

Results: While average total daily energy intakes were similar in both consumers and non-consumers of GUM, intakes of protein, saturated fat, and vitamin B12 were lower and intakes of carbohydrate, dietary fibre, iron, zinc, vitamins C and D were higher in consumers of GUM. These differences in nutrient intakes are largely attributable to the differences in composition between GUM and cow's milk. For both consumers and non-consumers of GUM, intakes of carbohydrate and fat were generally in line with recommendations while intakes of protein, dietary fibre and most micronutrients were adequate. For children consuming cow's milk only, high proportions had inadequate intakes of iron and vitamin D; however, these proportions were much lower in consumers of GUM.

Conclusions: Consumption of GUM reduced the risk of inadequacies of iron and vitamin D, two nutrients frequently lacking in the diets of young children consuming unfortified cow's milk only.

Growing up milks (GUM) are milk-based drinks with added vitamins and minerals intended for children aged 12-36 months. The regulatory status of GUM is currently under review in the European Union (EU) in the context of the proposed revision of Directive 2009/39/ EC of the European Parliament and of the Council of 6 May, 2009, on Foodstuffs intended for Particular Nutritional Uses (PARNUTS). The European Commission has recently requested the European Food Safety Authority (EFSA) to provide advice on the need for such milks for young children and their nutritional composition (1).

There are few data available on the role of GUM in the diets of young children in Europe. A recent study in French children (12 years) (2) showed that the use of GUM significantly reduced the risk of insufficiencies of a-linolenicacid, iron, vitamin C and vitamin D that were associated with the consumption of cow's milk only. A report from Germany has described the similarities and differences between the contribution of 200 ml GUM and 200 ml cow's milk (1.5% fat) to recommended intakes of energy and macro- and micro nutrients (3).

In Ireland, nationally representative data on food consumption in young children are available from the National Pre-school Nutrition Survey (NPNS) (4,5) which was carried out in 2010/11. The aim of the present study was to use data from the NPNS to compare the nutritional adequacy of two groups of 12-24-month-old Irish children by type of milk consumption: GUM together with cow's milk or cow's milk only.

Experimental methods

Study groups

Analyses were based on data from the Irish NPNS cross-sectional food consumption survey conducted in 2010-2011 to establish a database of habitual food and drink consumption in a representative sample of children aged 12-59 months (n= 500). A quota sampling approach was adopted using the most recently published Irish census (6) to achieve a sample of 125 children with in each of four age groups (12-23 months, 24-35months, 36-47 months and 48-59 months) with 50:50 male/female representation in each group. Children were recruited from a database of names and addresses of children compiled by' eumom' (an Irish parenting resource) (www.eumom.ie) or from randomly selected childcare facilities in selected locations. Written informed consent was obtained from the parents/ guardians of each child that participated in the survey. The study was carried out according to the guidelines laid down in the Declaration of Helsinki, and all procedures were approved by the Clinical Research Ethics Committee of the Cork Teaching Hospitals (Ref: ECM 4 (a) 06/07/10). Further details of the survey methodology are available at www.iuna.net.

Data for the present study were included from children aged 12-24 months with an average daily total milk intake of at least 300 g and consuming GUM ( ] 100g/day) to get her with cow's milk (consumers of GUM; n=29) or cow's milk only (non-consumers of GUM; n=56). Children who were breast fed or consuming follow-on formula were excluded.

Consumers of GUM were similar to non-consumers with respect to age (consumers of GUM 16.3 months; non-consumers of GUM 18.2 months) and parental socio-economic status (SES) (professional workers: consumers of GUM 72%, non-consumers of GUM 73%; non-manual workers: consumers of GUM 14%, non-consumers of GUM 14%; manual workers: consumers of GUM 13%, non-consumers 13%). However, the two groups differed from the general population of children under the age of 15 with regard to parental SES (professional workers: 53%; non-manual workers: 25%; manual workers: 22%) (6).

Food intake assessment

A 4-day weighed food diary was used to collect detailed food and beverage intake data. In all cases, the study period included at least one weekend day. The researcher made three visits to the participant and his/her caregiver during the 4-day period: an initial training visit to show how to keep the food diary and use the weighing scales; a second visit 24-36 h into the recording period to review the diary, check for completeness and clarify details regarding specific food descriptors and quantities; and avisit 1 or 2 days after the recording period to check the final days and to collect the diary. Caregivers were asked to record detailed information regarding the amount, type and brand of all foods, beverages and nutritional supplements consumed by the child over the 4-day period and where applicable the cooking method used, the packaging size and type and details of recipes and any leftovers.

A hierarchical approach to food quantification was used as follows:

1) Weighed (participant/manufacturer weights) aportable food scales (Tanitakd-400, Japan) was provided and the caregiver was given detailed instructions (including a demonstration) on how to use the food scales. This method was used to quantify 78% of foods and drinks consumed. A further 7% of weights were derived from manufacturer's weights. To facilitate the collection of such data, care givers were asked to collect all packaging of food and beverages consumed by the child in a storage bag provided.

2) A photographic food atlas for pre-school children (7) was used to quantify 6% of foods and beverages consumed.

3) A database of average portions of certain foods was compiled by the research team and was used to quantify 0.5% of foods and beverages consumed.

4) Food weights and average portions of foods estimated by the Ministry of Agriculture, Fisheries and Food (MAFF) (8) were used to quantify 1% of foods and beverages consumed.

5) Household Measures suchas teaspoon, tablespoon, and soon, were used to quantify 6% of foods and beverages consumed.

6) The researcher estimated portion sizes based on the child's previous eating patterns. This method was used to quantify 1.5% of foods and beverages consumed.

Estimation of nutrient intakes

Nutrient intakes were estimated using WISP# (Tinuviel Software, Anglesey, UK), which uses data from McCance and Widdowson's the Composition of Foods, fifth and sixth editions plus all nine supplemental volumes to generate nutrient intake data, as described elsew here (5). During the NPNS, modifications were made to the Irish Food Composition Database (9) to include all recipes of composite dishes, nutritional supplements, generic Irish foods that were commonly consumed, new foods on the market and all infant/toddler foods and milks that were consumed during the survey period. Informationon brands was also recorded.

Comparison of nutrient intakes with dietary reference values

Mean Daily Intakes (MDI) for carbohydrate and fat were compared to reference intake ranges recommended by EFSA for carbohydrate (4560% energy (%E) fro mage 1 year) (10) and for total fat (35-40% energy (%E) in the second and third year of life) (11). For dietary fibre, MDI were compared to the adequate intake of 2g/MJ as recommended by EFSA (10), while for protein, MDI were compared to the average requirement and the population reference intake (PRI) of 0.95 and 1.14g/kg body weight perday, respectively, for 1-year-olds and 0.85 and 1.03g/kg body weight perday, respectively, for 1.5-year-olds derived by EFSA (12).

Estimated Average Requirements (EAR) as established by the Department of Health (UK) (13) were used as cut-offs to estimate the proportion of children with inadequate intakes of micro nutrients (calcium; iron; zinc; vitamin A, C, B6, B12, folate, thiamine, riboflavin and niacin). This method has been shown to be effective in obtaining a realistic estimate of the prevalence of dietary inadequacy (14). For vitamin D, MDI were compared with the American Institute of Medicine (IOM) EAR (15) and the UK recommended nutrient intake (RNI) (13).

The risk of excessive intake of micronutrients was evaluated by comparing MDI to the Tolerable Upper Intake Level (UL). The UL is defined as the maximum level of total chronic daily intake of a nutrient (from all sources) judged to be unlikely to pose a risk of adverse heal the ffects in humans (16). Intakes were compared to respective ULs derived by EFSA/EUS cientific Committee for Food for vitamin D (17), retinol(18), vitamin B6 (19), folicacid (20), zinc (21) and by the Food and Nutrition Board in the United States for calcium (15), iron (22), and vitamin C (23).

Under-reporting

Data were analysed including and excluding under-reporters. Minimum energy intake (EI) cut-off points, calculated as multiples of Basal Metabolic Rate, were used to identify under-reporters of energy (24,25). Data shown include under-reporters (7%), as their removal did not change the overall trends observed.

Statistical analysis

Data analysis was conducted using PASW# for Windows version 18.0 (SPSS Inc., Chicago, IL, USA). Independent t-tests (parametric data) or the corresponding Mann Whitney tests (non-parametric data) were used to assess differences between energy and nutrient intakes of consumers and non-consumers of GUM.

Results

The nutritional composition of GUM available on the Irish market (three brands, for children aged 1year and over) and the average composition of whole cow's milk are shown in Table1. The two brands that are predominantly consumed by Irish children had identical composition. Compared to whole cow's milk, the GUM have similar energy and fat content, higher ratio of unsaturated to saturated fat, higher carbohydrate (lactose), and lower protein. Two brands contained dietary fibre (galacto-oligosaccharides/ fructo-oligosaccharides). For micronutrients, the most marked differences were for iron and vitamin D for which (unfortified) cow's milk contained very little while GUM contained nutritionally significant amounts.

The mean daily intake of total milk in consumers of GUM (558g) was higher than in non-consumers of GUM (480g); however, the difference was not statistically significant. In consumers of GUM, the mean daily intake of GUM was 386 gand the average contribution of GUM to total milk in take was 60%. MDI of consumers and non-consumers of GUM were similar for energy, total fat, sodium, calcium, thiamine, riboflavin, niacin, folate, and vitamin A. Compared to non-consumers, consumers of GUM had significantly higher intakes of carbohydrate, dietary fibre, iron, zinc, vitamin C, and vitamin D, and lower intakes of protein, saturated fat, vitamin B6, and vitamin B12 (Table2).

Table 1. *Nutritional composition of GUM and whole cow's milk*

	Composition per 100g	
	Whole cow's milk[1]	GUM[2]
Energy (kJ)	274	274-289
Protein (g)	3.3	1.5-1.8
Fat (g)	3.5	3.0 - 3.3
of which saturated (g)	2.2	0.8 - 1.3
of which unsaturated (g)	1.3	2.0 - 2.2
Carbohydrate (g)	4.5	7.4 - 8.5
Dietary Fibre (g)	0	0 - 1.2
Sodium (mg)	43	26 - 30
Calcium (mg)	118	78 - 86
Iron (mg)	0.03	1.2
Zinc (mg)	0.4	0.9
Thiamine (mg)	0.03	0.05 - 0.1
Riboflavin (mg)	0.23	0.11- 0.14
Vitamin B6 (mg)	0.06	0.04 - 0.06
Vitamin B12 (mg)	0.9	0.14 - 0.18
Total Niacin (mg)	0.8	0.4 - 0.5
Folate (mg)	8	12 - 13
Retinol (mg)	30	65 - 70
Vitamin D (mg)	Trace	1.5 - 1.7
Vitamin C (mg)	2	12 - 15

[1]McCance & Widdowson Composition of Foods® updated for total fat and saturated fat from Irish composition data.
[2] Manufacturer's information, range based on three products from two manufacturers.

Table 2. *Mean daily energy and nutrient intakes in Irish children aged 12-24 months by GUM consumer group*

	Composition of GUM (n=29)	Non-consumer of GUM (n=56)	P
Energy (kJ)	4.4	4.3	0.692
Protein (g)	**38.1**	**43.7**	**0.020**
Fat (g)	39.3	40.2	0.754
Saturated fat (g)	**16.1**	**20.3**	**0.002**
Carbohydrate (g)	**134.6**	**123.2**	**0.025**
Protein (%TE)	**14.3**	**17**	**0.000**
Fat (%TE)	33.2	35.1	0.089
Saturated fat (%TE)	**13.5**	**17.8**	**0.000**
Carbohydrate (%TE)	**48.4**	**44.6**	**0.010**
Dietary Fibre (g)	**13.2**	**10.2**	**0.000**
Sodium (mg)	840	1008	0.078
Calcium (mg)	902	996	0.086
Iron (mg)	**10.4**	**5.9**	**0.000**
Zinc (mg)	**7.3**	**5.1**	**0.000**
Thiamine (mg)	1	1	0.742
Riboflavin (mg)	1.7	1.9	0.080
Vitamin B6 (mg)	**1.2**	**1.4**	**0.003**
Vitamin B12 (mg)	**3.6**	**5.4**	**0.000**
Total Niacin (mg)	17.5	18.1	0.442
Folate (mg)	169	174	0.420
Vitamin A (mg)	969	759	0.088
Vitamin D (mg)	**9.2**	**2.1**	**0.000**
Vitamin C (mg)	**118**	**58**	**0.000**

Bold denotes significantly (PB0.05) different nutrient intakes between GUM consumer groups.

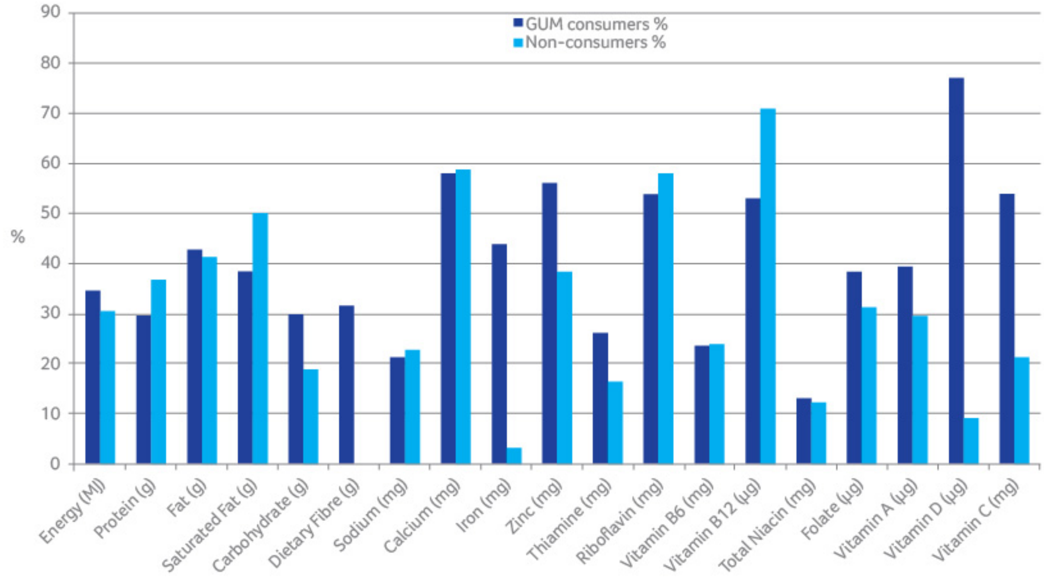
Milks were as ignificant source of energy for both consumers and non-consumers of GUM, contributing on average 31-35% of total energy intake (Fig.1). Milks also made a significant contribution in both groups to intakes of macronutrients and arange of micro nutrients, being more marked for consumers of GUM for dietary fibre, iron, vitamin C, and vitamin D. For both consumers and non-consumers of GUM, mean protein intake was 3.4 3.6g/kg body weight per day (equivalent to about three times the PRI) and there were no children with in takes of protein lower than the EAR indicating that protein intakes were adequate. Mean fat intakes were 33-35% energy and most children in both groups had fat intakes less than 40% E (93% of consumers of GUM, 80% of non-consumers of GUM). For carbohydrate, mean intakes were 45-48% energy, and consumers of GUM were more likely to have intakes greater than 45% Ethan non-consumers of GUM (79% vs. 57%, respectively). Mean dietary fibre intakes were 2.4 3.1g/ MJ and most consumers of GUM (93%) and non-consumers of GUM (77%) had intakes of dietary fibre greater than 2g/MJ. For both groups, there were very few children with intakes below the EAR for any micronutrient (calcium; zinc; vitamin A, C, B6, B12 folate, thiamine, riboflavin, niacin) except iron and vitamin D. For iron, 59% of non-consumers of GUM had intakes below the EAR but there were no children within takes low erth an the EAR among consumers of GUM. A high proportion of children in both groups had intakes of vitamin D below the IOMEAR of 10mg/day (consumers of GUM: 69%, non-consumers of GUM 98%). Consumers of GUM were less likely than non-consumers of GUM to have vitamin D intakes below the UKRNI of 7mg/day (31% consumers of GUM; 95% of non-consumers of GUM). A small number of children across the two groups exceeded the UL for zinc, retinol, and folic acid, but this was associated with consumption of GUM only for zinc.

Discussion

In this study of children aged 12-24 months, GUM were typically consumed in addition to whole cow's milk, contributing an average of 60% of total milk in consumers of GUM. In the NPNS (2010/11), GUM were reported to be consumed by 25% of children aged 12-24 months in Ireland where whole cow's milk was most widely consumed (88% consumers) and other milks consumed were reduced fat cow's milk (14%), breast milk (7%), follow-on formula (6%), and soya/rice milk alternatives (2%) (4). In that study, consumption of GUM was less common in children aged 25-36 months (14% consumers) (26).

The study shows the importance of milks as a food group in the diets of young children. In both consumers and non-consumers of GUM, total milks represented 31-35% of total energy intake and contributed significantly to dietary intakes of macronutrients and arange of micronutrients. While average total daily energy intakes were similar in both groups, intakes of protein, saturated fat, and vitamins B6 and B12 were lower, and intakes of carbohydrate, dietary fibre, iron, zinc, vitamins C and D were higher in consumers of GUM. These differences in nutrientin takes are largely attributable to the differences in composition between GUM and cow's milk. For both consumers and non-consumers of GUM, intakes of carbohydrate and fat were generally in line with reference intake ranges recommended by EFSA and intakes of protein and dietary fibre were adequate according to EFSA's recommendations. Intakes of micronutrients were generally adequate, except for iron and vitamin D.

Figure 1. *Contribution of total milk to mean daily energy and nutrient intakes in Irish children aged 12-24 months by GUM consumer group.*



For children consuming cow's milk only, a high proportion had intakes of iron that were below the EAR but there was no evidence of in adequate intakes among consumers of GUM. For vitamin D, almost all children consuming cow's milk only failed to achieve the IOMEAR of 10mg/day or the UKRNI of 7mg/day. However, for consumers of GUM, the proportions of children not achieving these reference intakes, while still significant, were much lower than in non-consumers of GUM. Iron and vitamin D are recognised as nutrients for which in adequate intakes have been reported in young children, and there is biochemical evidence of insufficiency for both these nutrients in this age group in Europe an countries (27-30). Furthermore, consumption of milk fortified with iron and vitamin D has been shown to improve body stores for these nutrients in healthy 12-to 20-month-old toddlers (31,32).

A small number of children across the two groups exceeded the UL for zinc, retinol, and folicacid, but this was associated with GUM consumption only for zinc. Because of the way in which UL has been set for these nutrients in children (i.e. estimated on the basis of body weight or body size from adult values derived using large uncertainty factors) (18,20,21), there is little risk of adverse effects occurring in the small proportion of individuals exceeding the UL by a modest amount.

There are similarities between the results of the present study and a recent study (2) in French children aged 12 years. That study also showed that consumption of GUM significantly reduced the risk of insufficiencies of iron and vitamin D, as well as of a-linolenic acid and vitamin C compared to French nutrient reference values.

A limitation of the present study is that it is based on small study groups of higher SES than the general population. However, the groups were similar to each other in terms of their mean age and socio-economic grouping allowing reliable comparisons to be made regarding the nutritional adequacy of the two groups.

Conclusions

In our study of Irish children aged 12-24 months, GUM were typically consumed in addition to whole cow's milk, contributing an average of 60% of total milk in consumers of GUM. Like cow's milk, GUM contributed significantly to intakes of energy, macronutrients, and arange of micronutrients. The main nutritional advantages of GUM consumption are in reducing risk of inadequacies of iron and vitamin D, two nutrients frequently lacking in the diets of young children consuming unfortified cow's milk only.

Conflict of interest and funding

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THAILAND NUTRITION IN TRANSITION: SITUATION AND CHALLENGES OF MATERNAL AND CHILD NUTRITION.

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Keywords: Mothers · Children · Early life · Nutrition transition · Thailand

Abstract

Double burden of malnutrition (DBMN), the coexistence of under-and overnutrition in the same population, is an emerging public health concern in developing countries, including Thailand. This paper aims to review the maternal and child nutrition situation and trends as the country moved from a low-income to a middle-income country, using data from large scale national surveys. Protein-energy malnutrition and micronutrient deficiencies predominantly affected mothers and children prior to the 1980s. The situation greatly improved during the 1980s-1990s, with the implementation of multi-sectoral policies and programs focusing on poverty alleviation and primary health care. Economic development, improved access to health services and effective community-based nutrition programs contributed to these positive trends. However, the prevalence of low birth weight remained at 8-10%, while stunting and underweight declined to about 10% by the 1990s, with small change thereafter. The prevalence of anemia among pregnant women and children decreased by half and vitamin A deficiency is no longer a public health problem. Iodine deficiency, especially during pregnancy is still a major concern. As the country progressed in terms of economic and social development, overnutrition among women and children affected all socio-economic levels. Changes in lifestyles, food access and eating patterns are observed both in urban and rural areas. Although efforts have been made to address these challenges, harmonized policy and strategic programs that address DBMN in the complex social and economic environment are urgently needed. Early life undernutrition should be considered along with measures to address obesity and chronic diseases in children.

Introduction

Thailand is known for its successful nationwide community-based nutrition program implemented during the 1980s to mid-1990s.[1-3] By mid-1990, industrial development to boost economic growth took precedence over health and social welfare. The wave of globalization and developments in communication technology brought about rapid changes in the lives and well-being of the Thai people. Thailand enjoys the reputation as a success story in nutrition, having achieved marked reductions in protein-energy malnutrition and micronutrient deficiencies among children and women within two decades. The change in lifestyle from agricultural to non-agricultural industrial occupations (such as, food, garments, information technology (IT) factories) resulted in a shift from labor-intensive rural farm work activities to sedentary factory work or office clerical work. As in other rapidly industrializing countries, the rise of overnutrition and its consequent health effects changed the nutrition and health situation of the Thai people.

The aim of this paper is to examine the current nutrition situation using information from national nutrition and health surveys in Thailand, focusing on the status of children and women. It will also review the existence of both under- and over –nutrition and implications for policy and research for the country.

Methods

Information on the prevalence and trends of key nutritional problems were obtained from nationally representative surveys. These are the national food and nutrition surveys (NNS series) and national health examination surveys (NHES series) and the multiple indicator cluster survey (MICS). Findings from relevant small scale studies (such as intervention studies) complemented the information obtained from nationwide surveys. Since the data used in this report were compiled from publications or reports which are available in the public domain, ethical clearance is not needed.

Sources of data

National Nutrition Survey

The National (Food and) Nutrition Survey (NNS) was first conducted in 1960 among military and civilian populations.[4] The sampling population consisted of households with children under 5 years old. All pregnant and lactating women in the same families or community were included.

Subsequent surveys were conducted approximately every 10 years.[5-7]

National Health Examination Survey

The first National Health Examination Survey (NHES) was conducted in 1991, focusing on the health status of the population above 15 years of age.[8] Health status and risk factors for non-communicable diseases (physical, biochemical and questionnaire) were reported in all NHES's. Data on children's nutritional status were limited in the first 3 surveys, but were more extensive in the fourth NHES.[9-11] In this latest survey, the food consumption and dietary intakes (using 24-h recalls and food frequency questionnaires) of different age groups, as well as child anthropometry, feeding practices and urinary iodine excretion (UIE) of children aged 1-14 years old were included.[12,13]

Multiple Indicator Cluster Survey

The Multiple Indicator Cluster Survey (MICS) was conducted by the National Statistics Office with support from UNICEF.[14] This survey provided additional data on maternal and child nutrition, focusing on child health and nutritional status and child feeding.

Results

Country demographic and economic status

Thailand has a population of about 64 million people as of 2010[15] with a relatively high literacy rate of >90%. The population is projected to decline in the next two decades. The successful family planning program in the country resulted in the latest population growth rate of 0.8 %. In 2009, fertility rate was 1.6%, with a birth rate of 13.87 children per 1000 population. Annually, there have been about 800,000 births. The proportion of children under 5 years old is 6% of the total population. In 2010, the proportion of elderly was 12%. This number is projected to rise to 16% by 2020. Life expectancy at birth is 70 and 78 years old for males and females, respectively. According to World Bank criteria, national economic development since the 1990s raised the country ranking in economic terms to a middle-income country. Economically, Thailand had a record annual growth rate of 9% during 1985-1995. Since the Asian economic crisis in 1997, Thailand has recovered with an annual growth rate of 5-7 %. The GDP per capita was USD 8,500 as of 2010, and 15 provinces with the lowest GDP were all in the northeastern region.[16]

Maternal and child malnutrition – Thailand success story

Since 1982, the nationwide implementation of Thailand's Poverty Alleviation Plan (PAP) in conjunction with Primary Health Care (PHC) has led to improved access and quality of health care even in rural poor areas.[19] Explicitly formulated interventions for maternal and child nutrition resulted in significant declines in malnutrition among mothers, infants and children under five. Reduction in mortality and morbidity due to common infections such as diarrhea and respiratory illness was also achieved. Currently, these rates are much lower than those in most developing countries.

Using data from MICS, Limwatananon et al, (2010)[20] examined the equality of various health indicators relating to mothers and children. They observed that stunting and teenage pregnancy concentrated among the poor, whereas incidences of diarrhea and respiratory infections were similar regardless of socioeconomic status. Child immunization and family planning services were equitably distributed across socioeconomic groups. A slight but negligible gap was observed between the poor and the rich in terms of coverage of prenatal care and child delivery by skilled personnel. Overall, the coverage of prenatal care and child delivery services was >95%, and the urban-rural gap for several health and health care indicators was quite small. This finding indicates that achievements made during the earlier two decades have been sustained.

Protein-energy malnutrition in women and children

Low birthweight (LBW)

In the 1980s, the prevalence of LBW in Thailand was about 12%, with some geographical differences.[22] The prevalence of LBW declined throughout 1990-2000 and has remained at 8-9%.[23,14] Data from MICS 2006, which included 98.7% of babies weighed at birth, showed that LBW prevalence was 9.2% with no significant difference by residential area and maternal education. There was a slight difference between poor and rich households (10% vs 8.5%, respectively). In some remote areas, very high prevalences of LBW (i.e., 20-25%) were observed.

In a cohort study, Isranurug et al (2007) reported that maternal age (<20 and >35 y; RR = 1.85, 95% CI:1.47- 2.33), maternal height (<145 cm; RR = 2.29, 95% CI: 1.57-3.34) and pregnancy weight gain (<10 kg, RR = 1.67, 95% CI: 1.24-2.26) were significant contributors to LBW.[24] Thirteen percent of mothers in this study were teenagers. Teenage mothers had higher rates of LBW (15.5%) compared to older mothers (8.8%).[25] Due to uncertainty in gestational estimation, lack of data on prepregnancy weight to accurately determine weight gain during pregnancy, and increased prevalence of teenage pregnancy, further investigation into the potential causes of low birth weight should be done to identify appropriate interventions.

Protein-energy malnutrition among children under five

Figure 1 presents the trend of stunting, wasting and underweight among children under five since 1987. Based on NCHS references or WHO growth standards, the prevalences of stunting and underweight have substantially declined since 1987, but remained at 10-12% for stunting and 10-15% for underweight during the past two decades. Wasting has been relatively low (5%) and no severe malnutrition among young children has been reported as a public health problem since the late 1980s. Despite the economic crisis that hit Thailand in 1997, rates of both stunting and underweight did not increase.[26] The prevalence of low birth weight increased slightly (from 8.2% in 1996 to 8.7% in 1998). There was a slight upward trend in school child underweight prevalence (14.9% in 1997), but this level decreased to 12.5% in the subsequent year.

Cross-sectional and longitudinal studies consistently showed that the prevalence of stunting increased after the first six months and was highest at 24 months of age.[14,29] The MICS showed that the highest stunting prevalence was at age 12-23 months, and there were no gender differences. A similar pattern was reported in a cohort study of Thai children from four geographical districts and Bangkok.[29] Children were weighed every 6 months during the first two years of age. The prevalence of stunting based on WHO growth standards rose from birth to six months (i.e., 6% to 6.9%), and increased rapidly at 12, 18 and 24 months (i.e., 9%, 14.6%, and 16.8%, respectively).[29] It was speculated that low breastfeeding rates after the first year and poor hygiene related to early provision of foods and drinks could have explained this pattern.

Infant and young child feeding practices

Breastfeeding.

For most Thai mothers, breastfeeding is the mode of feeding infants right after birth. The MICS (2006) reported that about 85% of mothers breastfed their babies within one day of birth.[14] However, the rate of exclusive breastfeeding was only 7.6% for 3 months and 5.4% for 6 months. After 6 months, less than half (42.6 %) of the babies received solid or semisolid food in addition to breast milk. Breastfeeding drastically declined in the second year, i.e., 31.6% and 18.7% of mothers breastfed at 12-15 months and 20-23 months, respectively.

The most recent child health survey showed that the rate of exclusive breastfeeding for 6 months was 7.1% while that for 3 months was 31%.[13] Water was customarily given to babies along with breast milk as it was perceived necessary in the hot climate of Thailand. Factors that contributed to unsuccessful breastfeeding were inadequate breast milk, mother's working status, and traditional practices that accompanied the early introduction of semi-solid and solid food. Maternal nutrition was generally improved with the high coverage of prenatal care, and food taboos and traditional practices of withholding nutritious foods appeared to be disappearing.[7]

A study in a university hospital child care unit in northern Thailand found that working mothers were less likely to breastfeed

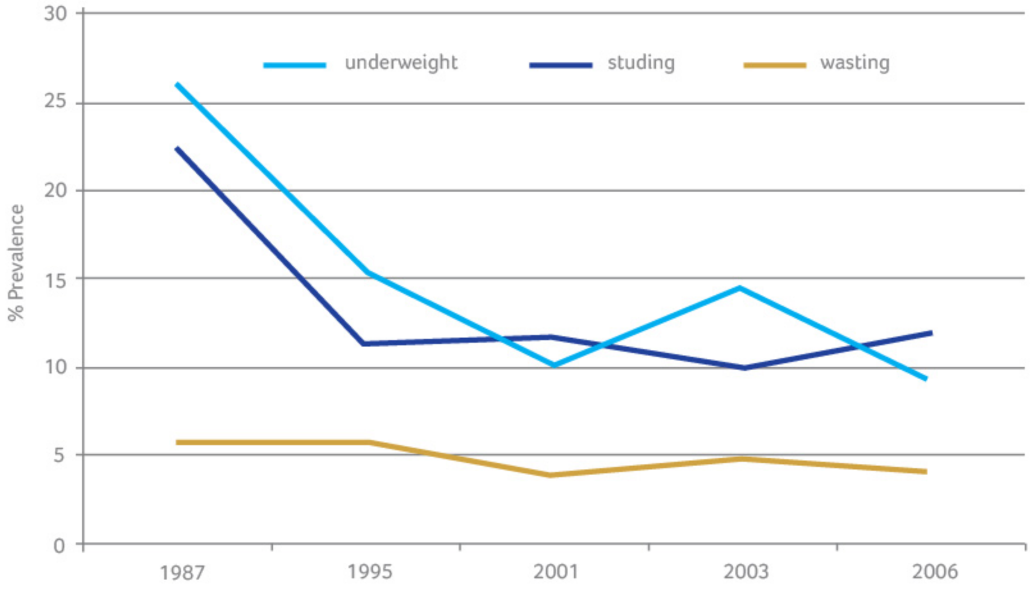

Figure 1. *Trend of nutritional status of children under five in Thailand based on national representative surveys using NCHS growth reference or WHO growth standard. Sources: 1. Thailand Demographic and Health Survey 1987[27] ; 2. National Nutrition Survey, Thailand 1995[6]; 3. Holistic Development of Thai children, 2001[28]; 4. National Nutrition Survey, Thailand 2003[7]; 5. Multiple Indicator Cluster Survey, Thailand 2006.[14]*

and the duration of breastfeeding was shorter. Seventy five percent of mothers who participated in the study were employed.[30,31] Only eighteen percent of employed women had a job which can be done at home.

The majority of working women spent about 10 hours away from home. Among non-working women, the prevalence of breastfeeding at 3, 6, and 12 months postpartum was 94%, 86%, and 66%, respectively. Among working mothers, breast feeding prevalences for the same period were 72%, 46% and 25%, respectively.

Complementary feeding.

In terms of complementary feeding, a large survey indicated that the introduction of solid foods and powdered milk occurred at an average age of 4 months.[13] In a child cohort study in 4 districts,[29] rice and banana were habitually given to infants within the first few months (Mo-suwan, L and Chittchang U, unpublished report). The timing of introduction of different foods varied by location. Rice and animal source foods were both introduced at around 4 months of age in Bangkok and in the northern district town. In the other four areas (all rural), rice was given early but animal food sources were delayed until the babies were 6 months to one year old.

The fourth health examination survey (2008-9) showed that meat, fish and egg are key protein sources for children aged 2-5 years.[12] Soybean milk was commonly consumed but pulses and nuts were not frequently eaten.

Consumption of fruits and vegetables was low. The median intakes of vegetables among the age groups 1-3 years and 4-5 years were 20 and 30 g, respectively for boys, and 7 and 16 g, respectively for girls. Fruit intakes were quite low, with a median of <1 g/day for all age and gender groups. In addition, per capita intakes of fat and protein as percentage of total energy intakes showed an increasing trend (Figure 2a). Various national nutrition surveys since 1986 showed that preschool children's percentage energy consumption from fat has been consistently above 20%, percentage energy consumption from protein increased only in the NHES4 (2008-9), and percentage energy consumption from carbohydrates decreased markedly (Figure 2b).[5-7, 12]

Micronutrient deficiencies

Iron deficiency and anemia

Anemia due to iron deficiency has been identified as a major public health problem in Thailand, and listed as a priority nutritional problem to be tackled in all national nutrition policies.[2] Iron and multivitamin supplementation is the main strategy to address maternal anemia.[32] Increased access to prenatal care and iron supplements helped improve the coverage and compliance to iron supplementation during pregnancy. Anemia prevalence in pregnant and lactating women declined from about 40% in 1986 (NNS3) to approximately 15% in 1995 (NNS4).[5,6] However, in 2003 (NNS5), the prevalence of anemia increased to 26% and 30% in pregnant and lactating women, respectively, while anemia among reproductive age women was 18.6% (Figure 3).[7]

During the period 1986-2003, the prevalence of anemia among children under five declined even though no supplementation program was implemented. It could only be speculated that the reduction of common infections due to effective implementation of primary health care programs, deworming, and improved diets may have contributed to this improvement. Recent field intervention studies on micronutrients showed that iron deficiency only contributes 10-25% of anemia in Thailand.[33-35] Other factors, namely, hemoglobinopathy and marginal vitamin A deficiency were also significantly associated with haemoglobin in children.[33]

Iodine deficiency

Data on urinary iodine excretion indicated that iodine intakes may be inadequate in some populations, specifically, pregnant women. Cyclical monitoring of urinary iodine excretion (UIE) of pregnant women utilizing prenatal services is conducted regularly (5 years for each round, with a sampling of 15 provinces/year). Almost half of the women examined had low UIE. In 2001, the first round of cyclical monitoring showed that over 40% of pregnant women had UIE <100 µg/L. The next round of monitoring (2006-2009), using the WHO new

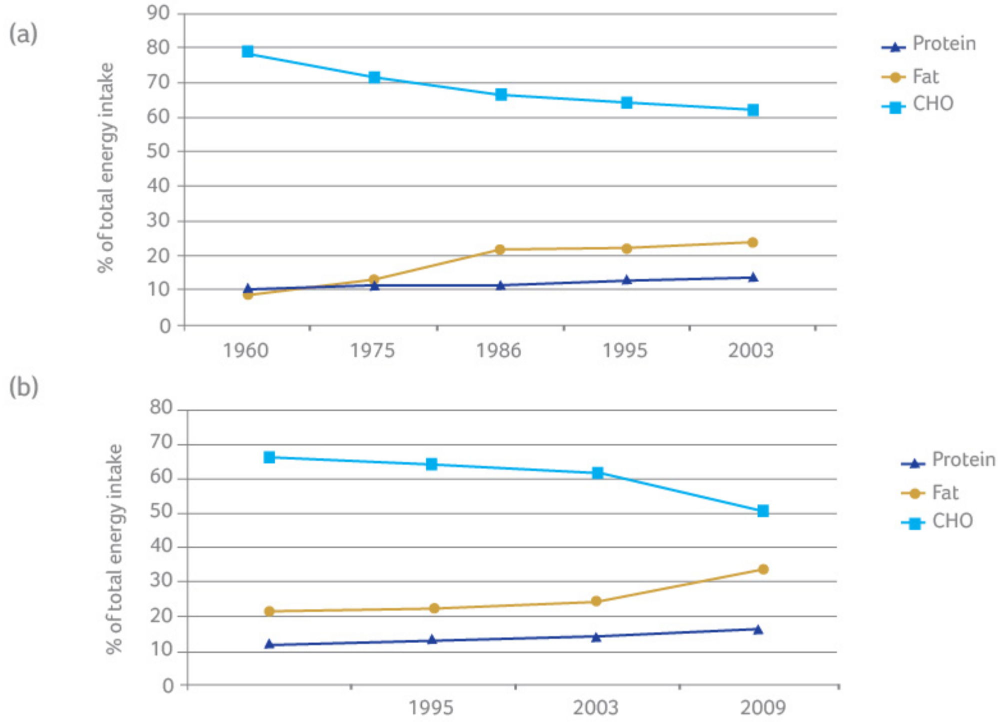

Figure 2. Percent of caloric distribution of macronutrient (protein, fat and carbohydrates) intakes in Thai diets (a) per capita; (b) pre-school children from: 1960-2009. Sources: 1. National nutrition survey, ICNND, 1960 [4]; 2. Per capita intakes are from National Nutrition surveys (1975, 1986, 1995 and 2003)[5-7] for most surveys, except NNS5 (2003) which was for 15-59 year olds; Intakes of preschool children from National Nutrition surveys (1975, 1986, 1995, 2003) and National Health Examination survey (2008-9).[12]

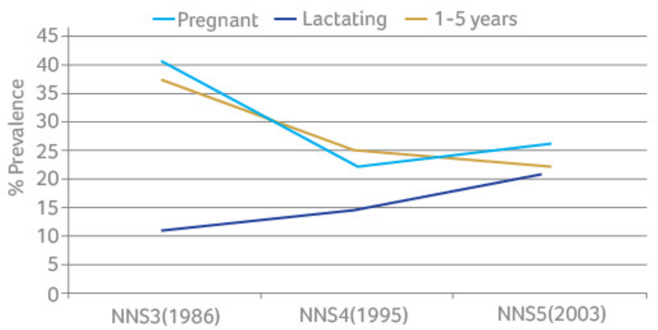

Figure 3. Prevalence of anemia among pregnant & lactating women and children under five. Sources: National Nutrition survey, 1986, 1995 and 2003.[5-7]

recommended cut-off for pregnancy (median <150 µg/L), showed that the prevalence of UIE below median was >50%.[36] A study among matched pairs of pregnant women and school-age children in central Thailand showed that pregnant women had lower median [range] UIE (108 [11–558] µg/L) compared to their school-aged children (200 [25–835]µg/L).[37] Another study using neonatal thyroid stimulating hormone (TSH) indicated that iodine deficiency disorder (IDD) is highly prevalent among pregnant women in Thailand.[38]

The most recent data collected in 2008-2009 showed that median UIE levels of children aged one year and 2-5 years old were 190 and 178 ▯g/L, respectively and the distribution appeared to be skewed towards high UIE values (Table 1).[13] The prevalence of UIE <100 µg/L among girls aged 1-5 years was 24.5-31%, slightly higher than that for boys (i.e.,~22%). The prevalence of UIE >200 µg/L was 30-40% for both boys and girls. A shift in distribution of UIE was observed wherein the prevalence of UIE <100 µg/L increased with age, while the prevalence of UIE >200 µg/L decreased with age. It is possible that young children who attended day care centers and primary schools received lunch and milk programs which used or contained iodized salt. Furthermore, iodization of drinking water in these schools in some areas may have provided higher amounts of iodine to young children.

Hence, while iodine intakes among children are adequate, low iodine levels among pregnant women is of serious concern since this is the critical period for fetal brain development. In 2010, the Ministry of Public Health (MOPH) implemented a new strategy for IDD, wherein iodine in addition to iron and other multi-vitamin/mineral supplements are given to pregnant women who attend the antenatal clinic. For the general population, strategies include improved quality of iodized salt and legislation for iodine fortification of condiments (fish sauce and soy sauce).

Other micronutrient deficiencies

Vitamin A.

Recent data indicate that vitamin A deficiency (VAD) is no longer a public health problem in Thailand. Food-based and holistic integrated nutrition programs may have contributed to the reduction of VAD. A survey in north and northeast Thailand found that the prevalence of marginal vitamin A deficiency among school and pre-school children was 20%.[39,40] A recent study showed that 3% of school children had deficient serum vitamin A levels (<0.7 µmol/L) and 20% had low levels (<1.05 µmol/L). In the national nutrition survey (NNS5, 2003), only 2% of reproductive age women were found to have vitamin A deficiency.[8]

Table 1. *Distribution of urinary iodine excretion (UIE) among preschool children and children aged 1-14 years*

UIE, µg/L / Age, y	Prevalence, %					
	≤ 20	20-49	50-99	100-199	200-299	≥300
Preschoolers , years						
Boys 1	0.08	4.8	17.2	37.5	19.0	21.5
Boys 2 -5	1.66	4.2	15.9	41.8	15.7	20.6
Girls 1	0.62	2.5	21.6	35	19.9	20.4
Girls 2 -5	1.31	3.94	25.6	33.1	20.6	15.5
Age groups, years						
1	0.8	4.5	16.6	39.4	17.5	21.1
2-5	1	3.2	23.5	34.1	20.3	18.1
6-9	1.3	6.5	27	36.9	16.6	11.8
9-14	1.5	7.2	33.4	36.7	12.6	8.6

Source: The Fourth National Health Examination Survey, NHES4, Child Health, 2008-9.[13]

Table 1. *Prevalence of overweight/ obsity by BMI and central obesity based on waist circumference among Thai adults*

Indicators	Prevalence of overweight/obesity (%)						
	15-29	30-44	45-59	60-69	70-79	≥80	Total
BMI †							
Males	18.5	32.2	33.7	26.4	18.6	11.3	28.4
Females	20.6	44.2	50.6	43.1	31.3	13.9	40.7
Waist circumference							
Males ‡	11.6	17.4	23.3	23.3	20	13.4	18.6
Females §	26.5	43.9	54.9	53.3	45.1	28.6	45

Source: The Fourth National Health Examination Survey, NHES4, 2008-9.[11]

† ≥ 25 kg/m²

‡ > 90 cm

§ > 80 cm

Zinc. It is not known whether zinc deficiency is a public health problem due to lack of appropriate indicators to define deficiency. The use of serum zinc concentration has been tentatively suggested by IZiNCG.[41] Two studies in infants and school children showed that 25% of young infants (4-6 months) and 57% of school-aged children (6-12 years) had serum zinc concentration in the deficient range.[35,42]

Remaining issues and emerging concerns in maternal and child nutrition

Early life nutrition, cognition and risk of diet related chronic disease in later life

Nutrition during the fetal period and throughout the first two years influences cognitive function and development of non-communicable chronic diseases in later life. Micronutrient deficiencies, namely iron, iodine and essential fatty acids, are shown to contribute to cognitive development and function, both in the short- and long-term.[43-46] A recent study in Thailand showed that growth in length during the prenatal and early infancy period significantly determined cognitive ability at 9 year.[47] The consequences of early life malnutrition (both under- and over-nutrition) include hypertension, diabetes and cardiovascular disease.[48-51] These issues are relevant to Thailand, as it transitioned from a low income country with a high prevalence of maternal and child undernutrition prior to the 1980s, to a more affluent country since the 1990s. This economic transition was accompanied by the reduction of severe maternal and child undernutrition, while stunting and subclinical multiple micronutrient deficiencies remain. Optimal nutrition from fetus through the early years should be a national agenda.

Childhood obesity and metabolic syndrome

Childhood obesity is of increasing concern in Thailand. Large scale surveys conducted after 2000 showed that overweight and obesity prevalence is 8-20% among pre-school children, and 5-16% among school-aged chil-dren.[52] The prevalence of overweight and obesity was higher among adolescents than among younger school-aged children. However, in these reports, different growth references (Thai or NCHS or WHO) and classification systems (either +2SD or >97 percentile as cut-offs) were used, making comparisons difficult. Using International Obesity Task Force (IOTF) criteria, the NHES4 (2008-2009) found that prevalences of overweight and obesity among preschool (2-4 years) and school-aged (6-14 years) children were comparable to those of developed countries in the region. Prevalence of overweight and obesity among pre-schoolers was 13.2% for both boys and girls; among school-age children, the prevalence was 16.7% for boys and 15.2% for girls.[13]

Data on the prevalence of the metabolic syndrome among overweight and obese children are limited. Nevertheless, Iamopas et al (2011)[53] found that 17% of 89 obese children attending a hospital in Bangkok had the metabolic syndrome. Another study from northeast Thailand reported the metabolic syndrome in 3.2% of over-weight adolescents, aged 10-15 years.[54] Of concern, adiposity in school-aged children was inversely related to iron deficiency and reduced response to iron fortification.[55]

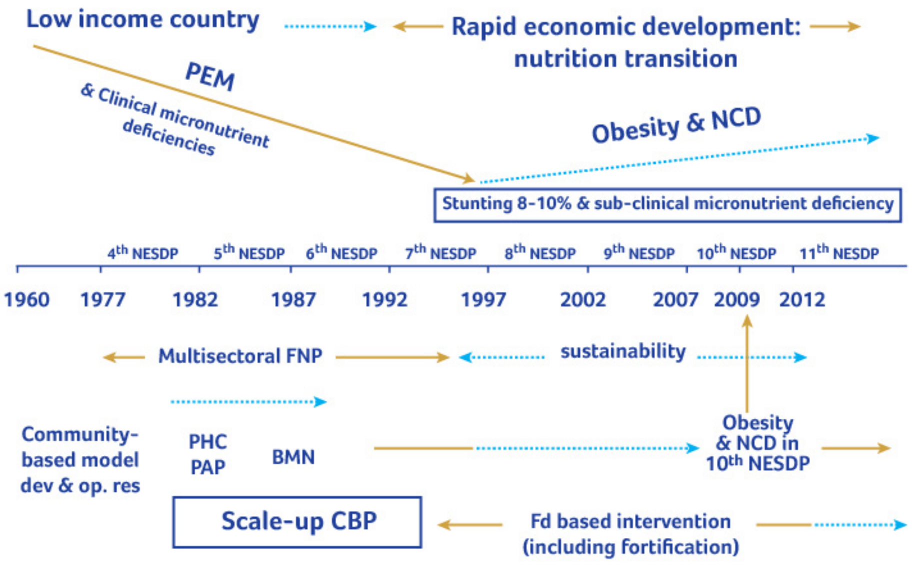

Figure 4. *Diagrammatic presentation of dynamism of nutrition situation in transition, and food & nutrition and relevant policies/ programs during 1960s-2000s in Thailand. NESDP: National economic and social development policy/plan; PHC: primary health care; PAP: poverty alleviation plan; BMN: Basic minimum needs; CBP: community-based nutrition program; PEM: protein-energy malnutrition; NCD: non-communicable diseases.*

Maternal nutrition and diet related chronic disease

Type 2 diabetes.
There is increasing evidence that the presence of gestational diabetes mellitus (GDM) and possibly, the intensity and duration of lactation are risk factors for developing type 2 diabetes among women in later adulthood.[56] However, no large scale study of GDM among Thai pregnant women has been done. Several hospital-based studies attempted to get estimates of GDM, especially among pregnant women who were defined as having high risk pregnancies. The incidence of GDM reported in various studies ranged from 2 to 7% of total pregnancies, or from 5 to 20% of pregnant women who were classified as having a high risk pregnancy or who were positive based on a glucose challenge test.[57-59] Studies differed in terms of the definitions used for high risk pregnancy and in the types of screening tests used for defining GDM. A cohort study in a hospital in northern Thailand reported that 3% of pregnant women had GDM. A follow up of these women after delivery showed there was a 3.7% probability of developing type 2 diabetes at 9 months, and an 18.9% probability of developing diabetes after 9 years.[60]

Obesity. It was observed that the prevalence of obesity among adult women was higher than among men (40.7% and 28.4%, respectively), using body mass index (BMI). The prevalence of central obesity measured by waist circumference was also higher among women than men (45% and18.6%, respectively) (Table 2).[11] It is speculated that weight retention as a result of pregnancy may partly contribute to obesity in later years, in addition to other risk factors. Adiposity in women was found to be related to lower iron absorption.[55]

Discussion

Thailand has made significant progress in alleviating maternal and child undernutrition through its effective community-based nutrition programs. With rapid economic and social development, changes in the environment inevitably brought about new challenges in nutrition. Undernutrition, namely, stunting and micronutrient deficiencies continue to exist, though at a much lesser magnitude and severity compared to many developing countries. The rapid rise in obesity and diet-related non-communicable chronic diseases in both children and women is of concern. Figure 4 depicts the progression of the nutrition situation since the mid-1970s and the future challenges in maternal and child nutrition.

The present demographic and epidemiological transitions in Thailand create a challenge in terms of having to deal simultaneously with marginal nutritional deficiencies, common infections, and lifestyle-related chronic conditions. Households are now less likely to produce their own foods, as purchasing foods is becoming common even in rural areas. In urban or semi-urban settings, local fresh food markets are still widespread. However, increasing numbers of minimart stores and supermarkets in these areas indicate the changing pattern of food access, especially for processed foods. Ready-cooked foods from street vendors or daily markets are common sources of family foods.[7] There has been increasing concern that freshly prepared street foods and processed foods contribute high levels of fat, sugar and salt in current Thai diets.

Based on the review findings, recommended policy actions and research include the following:

1) With very high workforce participation rates of women, it is necessary to identify strategies to increase breast feeding practices in the workplace. Campaigns or nutrition education alone are clearly inadequate, but factors related to working conditions of women need to be more closely examined.

2) To address the issue of low birth weight, information on pre-pregnancy BMI or weight gain during pregnancy should be collected in routine health information systems or large scale surveys. High rates of prenatal attendance provide a good opportunity to obtain these needed data. Importantly, further investigation is needed regarding the contribution of teenage pregnancy and preterm delivery to the high rate of LBW.

3) To address protein-energy malnutrition among children under five, child feeding during the first 24 months st feeding practices in the workplace. Campaigns or nutrition education alone are clearly inadequate, but factors related to working conditions of women need to be more closely examined.

2) To address the issue of low birth weight, information on pre-pregnancy BMI or weight gain during pregnancy should be collected in routine health information systems or large scale surveys. High rates of prenatal attendance provide a good opportunity to obtain these needed data. Importantly, further investigation is needed regarding the contribution of teenage pregnancy and preterm delivery to the high rate of LBW.

3) To address protein-energy malnutrition among children under five, child feeding during the first 24 months should be examined. Special efforts must be given to understanding the "why" and "how" of stunting and underweight, as well as increased childhood obesity. Identifying determinants of the double burden of malnutrition among children in the context of rapid economic transition will lead to formulation of appropriate policy and interventions. Promoting healthy and optimal growth and development of Thai children should be the way forward.

4) Due to increased prevalence of anemia among pregnant and lactating women, a review of program efficiency and compliance to iron supplementation during pregnancy may be needed. In addition, food-based approaches and other public health strategies including health promotion should consistently include anemia as part of the program. An evaluation of other factors that contribute to anemia, such as, hemoglobinopathy and vitamin A deficiency should be undertaken.

5) With improved quality of the iodization program (salt and other condiments), it is critical to monitor UIE levels in children to ensure that iodine intakes remain in the optimal range, and that the risk of exposure to excessive iodine in the food supply remains low. Proper monitoring of iodized salt quality and of women's compliance to iodine supplementation during pregnancy should be conducted. Impacts of the new policy should be evaluated in children, women of reproductive age, and pregnant women.

6) Due to changes in lifestyles, food access and eating patterns both in urban and rural areas, harmonized policy and strategic programs that address DBMN in the complex social and economic environment are urgently needed.

7) In order to develop programs addressing maternal nutrition and diet related chronic disease, a longitudinal study is needed to elucidate the impacts of weight gain during pregnancy and weight retention after pregnancy on the occurrence of obesity and other non-communicable chronic diseases in later adulthood among women.

8) Early life undernutrition should be considered along with measures to address obesity and chronic diseases in children. Emerging evidence shows that early life nutrition contributes to the occurrence of obesity and chronic diseases in later life, suggesting intergenerational effects of poor nutrition. Thus, innovative policy and program approaches are needed that go beyond short term specific interventions. Long term prospective studies that elucidate the relationships among determinants of malnutrition and their impact on health and human capital in a country in transition such as Thailand will be very important.

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Author Disclosures

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Thailand nutrition in transition:
situation and challenges of maternal and child nutrition

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TOTAL FLUID INTAKE AND ITS DETERMINANTS: CROSS-SECTIONAL SURVEYS AMONG ADULTS IN 13 COUNTRIES WORLDWIDE.

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Keywords: Fluid intake · Beverages · Adult population · EFSA adequate intake · Water · Liq.In7

Abstract

Purpose: To evaluate the total fluid intake from drinking water and beverages in adult populations from different countries and assess the percentage of individuals complying with the European Food Safety Agency (EFSA) adequate intake (AI) of water from fluids.

Methods: A total of 16,276 adults (7580 men and 8696 women) aged between 18 and 70 years (mean age 39.8 years) were randomly recruited from 13 different countries from three continents. Information about the total daily fluid intake (sum of drinking water and beverages) was collected using a 24-h fluid-specific record over seven consecutive days.

Results: Important differences in total fluid intake between countries were found; however, few differences between men and women were reported in most of the countries.

Less than 50 % of the women and approximately 60 % of the men do not comply with the EFSA AI of water from fluids. Women were more than twice as likely as men to meet these AI (OR 2.15; 95 % CI 2.02–2.29). The odds of meeting the AI of water from fluids were lower in individuals over 50 years (OR 0.88; 95 % CI 0.80–0.96). Nine percent of the total population consumed less than half of the AI, 40.5 % between 50 and 100 %, and 50.5 % more than the AI.

Conclusions: There were considerable differences in total fluid intake between countries but not between genders. Only 40 % of men and 60 % of women comply with the EFSA AI of water from fluids. Men and elderly individuals had an increased risk of not complying with this reference value.

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Introduction

Water is involved in practically all functions of the human body and plays a crucial role in life and health. Body water is essential not only for the digestion, absorption, metabolism and elimination of metabolites, but also for the structure and function of tissues and the maintenance of body temperature [1]. Dehydration can affect human health to such an extent that it can cause death. Even dehydration of only 1 or 2 % of body water has been shown to impair cognitive functions, alertness and capacity for exercise [2].

To keep the balance between water input and water losses, individuals are recommended to comply with the reference values of total water intake that have been established by some international societies or institutions [3, 4]. Total water intake includes water from drinking water, beverages of all kinds and food moisture. These reference values are largely based on observational studies of total water intake conducted in healthy individuals and the estimation of total water balance, which takes into account losses. However, the established reference values vary considerably, which can be partly explained by differences in the methodology used to estimate fluid intake and/or losses [5].

In most of the studies, food frequency questionnaires or 24-h recall was used to evaluate total fluid intake (sum of drinking water and beverages of all kinds). However, these questionnaires are designed to evaluate food intake and not fluid consumption as a whole. They usually focused only on the intake of solid foods and drinks, predominantly on those that provide calories. For this reason, and because fluids are often consumed outside mealtimes and not perceived as a food, fluid intake tends to be underestimated by as much as 500 mL/ day [6–9]. Also, most food records or dietary recalls do not capture the consumption of water; the consumption of other beverages is often underestimated by the individual or the interviewer [10]. This means that little is known about total fluid intake, so it is difficult to establish fluid recommendations on the basis of scientific evidence.

For this reason, the main aim of the present study is: (a) to evaluate the total fluid intake from beverages in adult populations from 13 countries in three continents, (b) to assess the percentage of individuals complying with the European Food Safety Agency (EFSA) adequate intake (AI) of water from fluids and (c) to assess the possible determinants of total fluid intake.

Methods

Design and study population

The present study is a cross-sectional analysis of original or published data collected in adults and elderly (≥18 years) by 13 different surveys conducted in Latin America (Mexico [11], Brazil and Argentina), Europe (Spain [12], France, UK [13], Germany, Poland and Turkey) and Asia (Iran [14], China [15], Indonesia and Japan) by public (Iranian National Nutrition and Food Technology Research Institute, NNFTRI, and Chinese Centre for Disease Control, CDC) and private organizations. The primary objective of these surveys was to assess the sources of fluid consumption, including drinking water and different types of beverages. The individual surveys took place between 2008 and 2014 and were referred to as Liq.In[7]. The participants in each country were randomly recruited either from a database of volunteers for population surveys or via systematic door-to-door recruitment until the quotas for age, gender, region, habitat and/or socioeconomic characteristics in relation to the total country population were met.

The following individuals were excluded from participating: those working in company advertising; marketing; market research; the media; the manufacture, distribution and sale of water; and all kinds of beverages. Likewise, people not able to read and write in the language of the questionnaire were not eligible to participate in the survey. Having a specific diagnosed disease and/or following a medically prescribed diet was additional exclusion criteria in UK, Iran and China. The surveys in Argentina, Poland and Japan also excluded participants who had taken part in a survey about nonalcoholic drinks in the previous 6 months. Participants who did not complete the full fluid intake record, participants reporting a mean total daily fluid intake below 0.4 L/day or higher than 6 L/day or those who had participated in a market research study in the previous 6 months were excluded from the analysis. Pregnancy or lactation was not a specific exclusion in the most countries, except in Iran and China. The effective sample size for the present study was 16,276 participants. Individuals who agreed to be part of the survey received detailed information about the survey's objectives, what was expected of them, and information about the study's provisions to preserve confidentiality, risks and benefits, and a clear explanation about their option to participate voluntarily or not in the study. After being given a fully informed description of the study, following the principles of informed consent, participants were asked for their oral approval to participate. No monetary incentive was offered for taking part in the study. All data were recorded anonymously. Therefore, subjects included in the dataset cannot be identi-fied, either directly or through identifiers. The survey protocol of the unpublished surveys was reviewed and approved by the University of Arkansas Review Board (ref. 14-12-376).

Assessment of total fluid intake

All participants were provided with a 24-h fluid-specific record so that they could collect information on their fluid intake over seven consecutive days. The 7-day fluid-specific record was always presented in the official language of the country. In all countries except France, Germany and Japan, a paper version of this 7-day fluid-specific record was delivered and explained to the participants during an initial interview at home. After a period of 7-days, the fluid record was collected from the participant's home by the researcher and checked with the participant. In France, Germany and Japan, participants completed 7-day fluid-specific record online. On the morning of the first day, these participants received an electronic reminder with written instructions on how to fill in the fluid record. Paper memory cards were made available to the participants so that they could make notes during the day and subsequently complete the fluid record online. Both the paper and online records had the same structure: The participants were asked the type and temperature of the beverage, the volume of the intake, the reason for the intake, and where and when it was consumed. The questionnaire also asked whether the fluid was consumed by itself or with some food, but did not record the food consumed. To assist the participants in estimating how much fluid was consumed, the records were supported by a photographic booklet of standard fluid containers. The questionnaire items on different types of fluids included: water (tap water, still bottled water and sparkling bottled water); hot beverages (coffee, tea and other hot bev-erages); milk and milk derivatives; regular sweet beverages (carbonated soft drinks, noncarbonated soft drinks, juices, energy drinks, sports drinks, other sugared soft drinks); diet sweetened beverages (diet carbonated soft drinks, diet noncarbonated soft drinks, other diet soft drinks); and alcoholic drinks. Total fluid intake was defined as the sum of all these categories.

The percentage of individuals following the EFSA adequate intake of water from fluids was calculated. The EFSA sets an AI of total water intake for men and women at 2.5 and 2 L, respectively. The sources of this water can be food moisture, drinking water and different types of beverage. The EFSA assumes that foods usually contribute about 20 % of total water intake [3]. Therefore, we set the AI of water from fluids, preferably water, to be at 2 L/day for men and 1.6 L/day for women. Within this manuscript, we will as of now on refer to these values as AI of fluids.

Assessment of socioeconomic and anthropometric variables

Socioeconomic level was assessed using a self-administered questionnaire in most of the countries and was categorized using the Market Research Society classification [16, 17].

Height in meters (m) and weight in kilograms (kg) were self-reported by participants, except in Poland, Iran and China where these variables were measured. The body mass index (BMI) was calculated (kg/m^2). In Mexico, Brazil, Argentina, Indonesia and Japan, no anthropometric data were available.

Statistical analysis

Data are presented either as means and 95 % confidence intervals (95 % CI), medians and 25th and 75th percentiles for continuous variables, or numbers and percentages for dichotomous variables. We compared the distribution of the selected characteristics between groups using χ^2 tests for categorical variables or Student's tests or analysis of variance (ANOVA), as appropriate, for continuous variables. Logistic regression models were fitted to assess the associations between compliance with the AI of fluids for total fluid intake (dependent variable) and gender (two categories) or age categories (four categories) as exposure. The models were adjusted for gender (except when gender was the independent variable), age in years (except when age categories were the independent variable), BMI in kg/m^2 and socioeconomic

Table 1. *General characteristics of the study population, categorized by country*

	Gender (%)		Age (years)	Age categories (years) (%)				BMI (kg/m^2)	Socioeconomic level (%)		
	Men	Women		18–29	30–39	40–49	≥ 50		AB	C	D
Mexico (n = 1498)	38.3	61.7	38.4 (37.7, 39.2)	34.0	20.8	19.6	25.7	ND	6.7	45.6	47.7
Brazil (n =1924)	48.9	51.1	34.6 (34.1, 35.1)	38.1	26.5	25.5	9.9	ND	20.1	45.5	34.4
Argentina (n = 507)	47.5	52.5	37.4 (36.3, 38.6)	37.5	21.1	17.8	23.7	ND	8.5	55.4	36.1
Spain (n = 1240)	50.8	49.2	42.9 (42.1, 43.7)	19.0	23.5	24.8	32.7	25.6 (25.4, 25.8)	25.4	70.8	3.8
France (n =1534)	52.4	47.6	44.7 (43.9, 45.4)	18.8	19.8	21.3	40.1	25.2 (25, 25.5)	ND	ND	ND
UK (n = 897)	41.4	58.6	43.9 (42.9, 44.9)	18.4	24.1	23.2	34.3	27.2 (26.7, 27.6)	17.3	53.4	29.3
Germany (n = 1868)	45.8	54.2	42.9 (42.3, 43.5)	17.0	21.3	28.7	33.0	26.2 (26, 26.5)	ND	ND	ND
Poland (n =1062)	48.7	51.3	46.1 (45.1, 47.1)	19.5	19.9	17.8	42.8	26 (25.8, 26.3)	10.0	73.0	17.0
Turkey (n = 961)	50.8	49.2	34.4 (33.7, 35)	38.1	27.6	23.4	10.9	25 (24.7, 25.3)	ND	ND	ND
Iran (n = 572)	49.5	50.5	36.9 (35.9, 37.9)	36.0	26.0	19.8	18.2	25.3 (24.9, 25.7)	22.6	34.4	43.0
China (n =1466)	50	50	39.4 (38.8, 40)	24.7	25.4	25.8	24.1	22.7 (22.5, 22.8)	ND	ND	ND
Indonesia (n =1366)	32.5	67.5	35.2 (34.6, 35.9)	39.3	27.6	17.3	15.7	ND	25.8	55.4	18.7
Japan (n =1381)	50.5	49.5	ND	26.4	27.2	21.3	25.1	ND	ND	ND	ND
Total population[a] (n =16,276)	46.6	53.4	39.8 (39.6, 40.1)	27.5	23.9	22.7	25.9	25.1 (25, 25.2)	17.5	54.3	28.1

Data expressed as mean (95% CI) or percentage
BMI body mass index, ND no data
[a]Include only those countries with data available on the presented characteristics

characteristics (lower and middle-low, middle, upper-middle and high). All statistical tests were two-tailed, and the significance level was set at $p < 0.05$. All analyses were performed using the SPSS software ver-sion 22.0 (SPSS Inc, Chicago, IL).

Results

The present analysis was conducted in a total of 16,276 participants (7580 men and 8696 women) from 13 countries. The baseline characteristics of participants are summarized in Table 1. The mean age of the population was 39.8 years old, with a range between 18 and 87 years. A total of 25.9 % of the population were more than 50 years of age, 22.7 % were between 40 and 49 years of age, and 23.9 and 27.5 % were between 30 and 39, and 18 and 29, respectively. The participants had a mean BMI of 25.1 kg/m^2, and more than half had a low or middle-low socioeconomic level.

Table 2 shows the median and distribution in percentiles of the total fluid intake by country. The median total fluid intake for the total population was 1.98 L/day. Few differences were observed in the median consumption of total fluid intake between men and women in most of the countries. Germany had the highest total fluid intake (2.47 L/day), and Japan the lowest (1.50 L/day). As shown in Fig. 1, the percentage of individuals meeting with the AI of fluids varied considerably between countries. Women were more likely to comply with AI of fluids. A total of 59.2 % of women complied with the reference value of 1.6 L, whereas only 40.6 % of men complied with the reference value of 2 L. In all the countries included in this analysis, a higher percentage of women complied with the AI of fluids. Only in five of the 13 countries, more than 50 % of the men comply with the AI of fluids.

Figures 2 and 3 show the adjusted odds ratio (OR) (95 % CI) of complying with the AI of fluids, for gender and age range, respectively. When the analysis of total population was stratified by gender (Fig. 2), women were more than twice as likely as men to meet the AI of fluids (OR 2.149; 95 % CI 2.02–2.29). In all the countries, men were at greater risk than women of not complying with the AI of fluids. When the total population was stratified by age (Fig. 3), we observed that participants between 30 and 39 years old had a nonsignificant 3 % lower probability of complying with the AI of fluids, whereas individuals of over 50 years of age presented a significant 12.4% lower probability of compliance in comparison with the age range 18–29 years old. In terms of compliance with the AI of fluids, no differences were found between individuals of 40–49 years of age and those younger than 29 years.

Table 3 shows the percentage of the population that complied with the AI of fluids according to adequacy percentage categories. Of the total population from the different countries, 9.0 % did not consume even half of the reference value, 40.5 % consume between 50 and 100 %, and 50.5 % consume the adequate intake set by EFSA. Japan had the highest percentage of population (17.1 %) that consumed less than half of the AI of fluids, and the UK was the country with the lowest (1.2 %). Germany had the highest percentage of individuals complying with AI of fluids (73.8 %), whereas Japan had the lowest (28.8 %).

Discussion

The main objective of the present innovative study is to estimate total fluid intake (water and other beverages) and assess the percentage of individuals who comply with the EFSA adequate intake of water from fluids (drinking water and beverages of all kinds). We report that less than 50 % of the women and approximately 60 % of the men from 13 different countries did not comply with the adequate intake values of water from fluids.

To the best of our knowledge, to date, only a few national population-based studies conducted on healthy individuals [18–27] have reported total fluid intake as a primary outcome. Of these, only four used a 7-day record to evaluate the total fluid intake [15, 19–21], while the others used dietary records of 4 days or less. Only one used a 7-day fluid-specific record [15].

Table 2. *Total fluid intake in L/day, categorized by country*

	Mean (SD)	Percentiles						
		5	10	25	50	75	90	95
Total population (n = 16,276)	1.98 (0.95)	0.77	0.93	1.27	1.80	2.49	3.28	3.81
Mexico (n = 1498)	1.81 (0.97)	0.66	0.79	1.12	1.59	2.31	3.13	3.73
Brazil (n = 1924)	2.22 (1.11)	0.82	1.00	1.40	2.00	2.80	3.75	4.50
Argentina (n = 507)	2.30 (0.99)	1.02	1.17	1.59	2.15	2.88	3.63	4.28
Spain (n = 1240)	1.90 (0.81)	0.82	0.99	1.33	1.77	2.35	2.98	3.43
France (n = 1534)	1.56 (0.67)	0.68	0.80	1.08	1.45	1.94	2.46	2.82
UK (n = 897)	2.32 (0.86)	1.12	1.32	1.68	2.19	2.83	3.46	3.95
Germany (n = 1868)	2.47 (0.89)	1.00	1.27	0.83	2.46	3.08	3.71	3.98
Poland (n = 1062)	1.64 (0.54)	0.86	1.00	1.24	1.57	1.96	2.40	2.62
Turkey (n = 961)	2.21 (1.06)	0.89	1.06	1.44	2.02	2.76	3.58	4.22
Iran (n = 572)	1.92 (0.80)	0.87	1.03	1.33	1.81	2.33	3.03	3.34
China (n = 1466)	1.76 (0.92)	0.66	0.81	1.13	1.56	2.16	2.96	3.62
Indonesia (n = 1366)	2.28 (1.02)	0.91	1.05	1.48	2.13	2.96	3.78	4.22
Japan (n = 1381)	1.50 (0.64)	0.61	0.76	1.02	1.40	1.88	2.36	2.72
Men (n = 7580)	1.97 (0.96)	0.77	0.92	1.26	1.78	2.48	3.27	3.84
Mexico (n = 574)	1.77 (0.92)	0.63	0.76	1.10	1.58	2.24	3.09	3.66
Brazil (n = 941)	2.34 (1.16)	0.85	1.05	1.45	2.10	3.00	4.00	4.70
Argentina (n = 241)	2.32 (0.94)	1.06	1.19	1.67	2.13	2.87	3.60	4.22
Spain (n = 630)	1.94 (0.84)	0.80	0.99	1.34	1.80	2.37	3.01	3.52
France (n = 804)	1.55 (0.66)	0.69	0.80	1.08	1.43	1.93	2.41	2.82
UK (n = 371)	2.24 (0.82)	1.08	1.30	1.62	2.15	2.80	3.25	3.78
Germany (n = 856)	2.51 (0.94)	0.92	1.21	1.81	2.43	3.06	3.73	4.03
Poland (n = 517)	1.70 (0.53)	0.94	1.10	1.31	1.63	2.04	2.47	2.67
Turkey (n = 488)	2.15 (1.01)	0.90	1.05	1.42	1.93	2.70	3.49	4.03
Iran (n = 283)	1.92 (0.78)	0.89	1.04	1.33	1.80	2.37	3.03	3.33
China (n = 733)	1.78 (0.95)	0.68	0.82	1.12	1.57	2.16	3.02	3.82
Indonesia (n = 444)	2.33 (1.08)	0.94	1.07	1.47	2.18	2.99	3.93	4.41
Japan (n = 698)	1.47 (0.63)	0.59	0.72	1.01	1.39	1.84	2.28	2.66
Women (n = 8696)	1.98 (0.95)	0.78	0.93	1.28	1.81	2.50	3.29	3.80
Mexico (n = 924)	1.84 (1.00)	0.69	0.80	1.12	1.60	2.34	3.20	3.82
Brazil (n = 983)	2.10 (1.05)	0.80	0.97	1.30	1.90	2.57	3.51	4.20
Argentina (n = 266)	2.29 (1.04)	0.99	1.13	1.50	2.15	2.93	3.74	4.41
Spain (n = 610)	1.87 (0.79)	0.83	0.97	1.32	1.73	2.29	2.89	3.37
France (n = 730)	1.57(0.61)	0.67	0.78	1.08	1.44	1.97	2.50	2.81
UK (n = 526)	2.37 (0.88)	1.17	1.34	1.75	2.23	2.89	3.58	4.07
Germany (n = 1012)	2.45 (0.90)	0.96	1.23	1.78	2.44	3.07	3.62	3.94
Poland (n = 545)	1.57 (0.55)	0.77	0.94	1.19	1.51	1.88	2.32	2.573.53
Turkey (n = 473)	2.27 (1.11)	1.08	1.20	1.55	2.00	3.05	3.88	4.59
Iran (n = 289)	1.92 (0.82)	0.86	1.02	1.33	1.83	2.27	3.04	3.40
China (n = 733)	1.75 (0.89)	0.66	0.80	1.14	1.56	2.17	2.92	3.54
Indonesia (n = 922)	2.26 (0.99)	0.88	1.04	1.48	2.10	2.95	3.68	4.11
Japan (n = 683)	1.52 (0.65)	0.66	0.79	1.04	1.42	1.93	2.41	2.75

Our study reported a higher total fluid intake than other investigators have reported for the same countries [19–21]. This may be because a prospective fluid-specific questionnaire was used, which enabled participants to better register all the sources of fluid consumption. For example, a previous study that evaluated total fluid intake in an adult population of 20–54 years old from France revealed that the median fluid consumption was 1300 mL/day and that intake was lower in older individuals [21]. In contrast, our study found that the total median fluid intake for France was 1560 mL/day. Although the authors did not evaluate the percentage of participants who did not comply with the EFSA reference values of total water intake, their results suggest that a high percentage of the French population are at risk of an inadequate intake. In

Fig. 2. *Percentage of participants complying with EFSA adequate intake of water from fluids, by country and gender. ᵃp value <0.001*

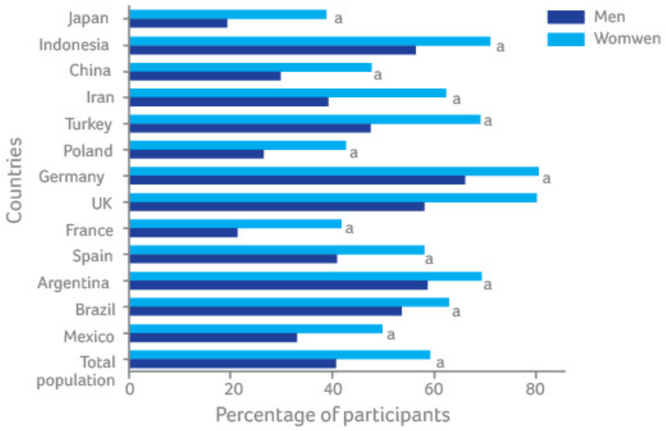


Fig. 2. *Association between compliance with EFSA adequate intake of water from fluids (outcome) and gender (exposure) according to countries. Men were considered as reference. Logistic regression model adjusted for age, body mass index and socioeconomic level. 95 % CI 95 % confidence interval*

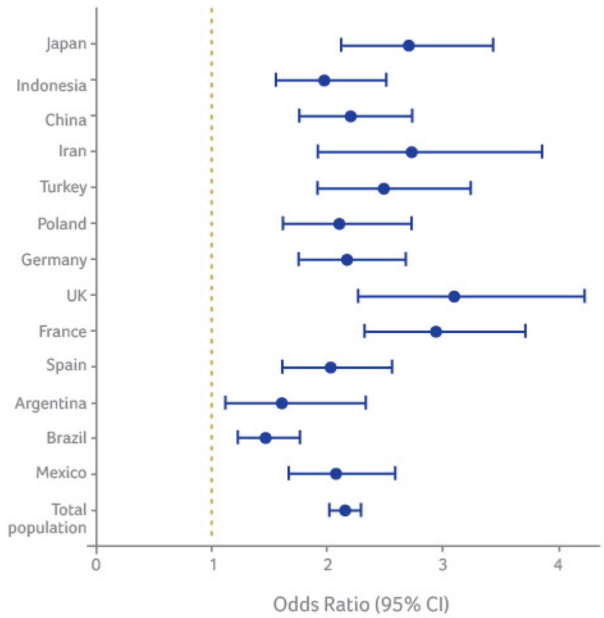
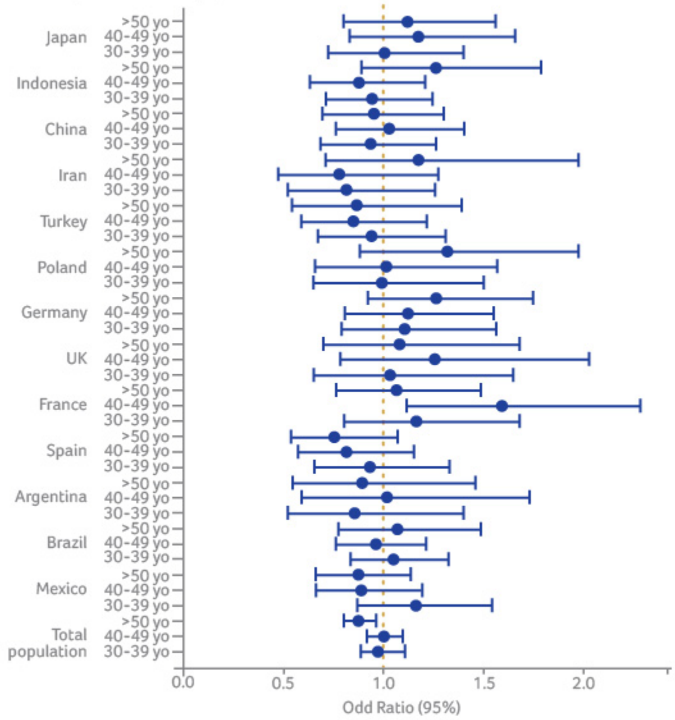


Fig. 3. *Association between compliance with EFSA adequate intake of water from fluids (outcome) and age categories (exposure), accord-ing to countries. The 18–29 age range was considered as reference. Logistic regression model adjusted for gender, body mass index and socioeconomic level. 95 % CI 95 % confidence interval, yo years old.*



Germany, in 2011, total fluid intake recorded by adults with a of the French population are at risk of an inadequate intake. In Germany, in 2011, total fluid intake recorded by adults with a 7-day food record was found to be only 1526 mL/day for men and 1214 mL/day for women [20]. Our study found the median total fluid intake in Germany to be remarkably higher (approximately 2510 and 2450 mL/day for men and women, respectively), which means that a higher percentage of German males and females comply with the AI of fluids. In the UK [19], previous reports of median total fluid intake (1900 mL for men and 1520 mL for women) are also lower than the findings of the present study (2240 and 2370 mL for men and women, respectively).

Our study is the first that enables total fluid intake to be compared between countries because the same methodology of data recording was used in all the surveys. Germany and the UK were the countries where the highest percentages of the population complied with the AI of fluids, whereas Japan was the country with the lowest. It is difficult to find a physiological reason for these between-country differences. The well-known and described differences in climate conditions (temperature and humidity) between countries cannot explain the differences found in our study because some warm countries (where fluid demands should be higher) had lower total fluid intakes than cold ones. However, these differences may be partly explained by the fact that not all surveys were carried out in the same season, even though all surveys aimed to perform data collection during the period of mild climate (spring or autumn). It is accepted that temperatures are more extreme during the summer, so fluid intake and loss are also expected to be higher. Water needs in summer increase because water loss through sweat higher than in winter [18]. Another issue that must be noted is that, in summer, habits of adapting environmental conditions (air-conditioned or heating rooms) are less similar than those in winter. However, we cannot discount that other social determinants of fluid intake may explain some of the differences observed between countries in the present study [28, 29].

Although total fluid intake may well be expected to be different between men and women because of well-recognized differences in body surface and composition, our study found no significant differences in total fluid intake between genders in most of the countries. This adds further weight to the argument that social or educational aspects may play an important role in determining total fluid consumption. In this regard, it has been frequently reported that women in developed countries tend to have a healthier lifestyle pattern than men [28] and it is generally accepted that adults with a healthier dietary pattern usually have a healthier fluid pattern (that is to say, an increased consumption of water and total fluids) [29]. This also may explain the positive association between complying with the AI of fluids and being women in all

Table 3. *Percentage of the population by adequacy percentage categories, achieving EFSA adequate intake of water from fluids.*

	≤ 50 %	50–75 %	75–100 %	>100 %
Mexico (n = 1498)	13.5	22.4	20.8	43.3
Brazil (n = 1924)	7.5	16.6	17.7	58.2
Argentina (n = 507)	2.8	13.2	19.9	64.1
Spain (n = 1240)	7.4	17.1	26.2	49.3
France (n = 1534)	15.9	28.2	25.0	30.9
UK (n = 897)	1.2	10	17.8	70.9
Germany (n = 1868)	4.1	7.9	14.2	73.8
Poland (n = 1062)	6.1	26.5	32.8	34.7
Turkey (n = 961)	5.8	16.8	19.5	58.4
Iran (n = 572)	5.3	21.2	23.1	50.5
China (n = 1466)	14.1	23.6	23.7	38.7
Indonesia (n = 1366)	2.7	15.5	15.6	66.2
Japan (n = 1381)	17.1	29.8	24.2	28.8
Total population (n = 16,276)	9.0	19.3	21.2	50.5

the countries evaluated.

Several potential limitations of our study need to be considered. Although all samples were randomly selected from a database of volunteers for population-based surveys or through a door-to-door recruitment process using the same quota sample method, which led to a large representative sample of adults in each country for the stratum considered [30], the populations in our study are not fully representative of the general population of each country. Nevertheless, the final distribution of the individuals studied among age groups, gender, regions and educational categories was very similar to the real distribution of the population of each country studied. The second limitation is inherent to the survey itself: The method used to collect anthropometric (reported or measured) and socioeconomic data was not the same in each country, and in some surveys, this information was not assessed. However, this information was only used to characterize the samples and would not influence the main outcome. Third, because we have only assessed the total fluid intake and no biomarkers of hydration status were used, no conclusions about the risk of dehydration and health can be drawn. Finally, the 24-h fluid-specific record over 7 days used in the present study must be validated in the future with gold-standard methods, in order to have the certainty that total fluid intake is reliably assessed.

The most relevant strength of this analysis is that it reports for the first time the description of total fluid intake of 16,276 participants in 13 countries from three continents. Moreover, a unique 24-h fluid-specific record over seven consecutive days was used that focused on selfreported total fluid intake, encompassing different types of fluids and was supported by visual aids, to facilitate recall and recording. This is the first time that the actual fluid pattern of a large sample of adults is recorded for all of these countries and valuable information is provided about the real differences in fluid intake between and within countries. This information suggests that if the reference values of water from fluids would be improved in the future, there should be a particular emphasis on those population groups found to be more at risk of not drinking enough, specifically the male gender and the elderly.

In conclusion, there were considerable differences in total fluid intake between countries but not between genders. For all the countries, only 40 % of men and 60 % of women comply with the EFSA adequate intake of water from fluids. Men had an increased risk of not complying with the EFSA adequate intakes of water from fluids. In most countries, elderly individuals had an increased risk of not complying with these adequate intakes. These results signify that a considerable portion of the study populations is potentially a risk of hydration-related health consequences such as chronic kidney disease [31]. Therefore, there is a clear need for additional longitudinal studies confirming the possible effects on health of an inadequate intake of water from fluids. Moreover, since there is merging evidence that a low fluid intake is a potential risk factor for health, the reference values of total water intake should be translated into practical recommendations for the general population and are ideally supported with community interventions.

Acknowledgments

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Conflict of interest

C.F.-P. and J.A. reports no conflicts of inter-est. J.S.-S, L.A.M., S.A.K., J.G., H.M. are members of the scientific advisory board on fluid intake of Danone Research. S.A.K. has received research grants form Danone Research. B.S. has received research grant from R&D AQUA Group, Indonesia. A.M and N.E. have received research grant/consultancies from Damavand Mineral Water Company, Iran. J.S.-S. J.G. and N.B. have received consultancies from Danone S.A. IG is an employee of Danone Research.

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INTAKE OF WATER AND DIFFERENT BEVERAGES IN ADULTS ACROSS 13 COUNTRIES

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Abstract

Purpose

To describe the intake of water and all other fluids and to evaluate the proportion of adults exceeding the World Health Organisation (WHO) recommendations on energy intake from free sugar, solely from fluids.

Methods

A total of 16,276 adults (46 % men, mean age 39.8 years) were recruited in 13 countries from 3 continents. A 24-h fluid-specific record over 7 days was used for fluid assessment.

Results

In Spain, France, Turkey, Iran, Indonesia and China, fluid intake was characterised by a high contribution of water (47–78 %) to total fluid intake (TFI), with a mean water intake between 0.76 and 1.78 L/day, and a mean energy intake from fluids from 182 to 428 kcal/day. Between 11 and 49 % of adults exceeded the free sugar WHO recommendations, considering solely fluids. In Germany, UK, Poland and Japan, the largest contributors to TFI were hot beverages (28–50 %) and water (18–32 %). Mean energy intake from fluids ranged from 415 to 817 kcal/day, and 48–62 % of adults exceeded free sugar WHO recommendations. In Mexico, Brazil and Argentina, the contribution of juices and regular sugar beverages (28–41 %) was as important as the water contribution to TFI (17–39 %). Mean energy intake from fluids ranged 565–694 kcal/day, and 60–66 % of the adults exceeded the free sugar WHO recommendation.

Conclusions

The highest volumes recorded in most of the countries were for water, mean energy intake from fluids was up to 694 kcal/day, and 66 % of adults exceeded the free sugar WHO recommendation solely by fluids. Actions to create an environment in favour of water consumption and reduce sugar intake from fluids therefore are warranted.

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Introduction

Total fluid intake (TFI) or its biomarkers have been associated with health outcomes such as the recurrence of kidney stones, renal function, new-onset hyperglycaemia and the prevalence of some components of the metabolic syndrome [1–4]. Therefore, assessing the volume of TFI in populations is important from a public health perspective.

In addition, it is also important to assess the intake of different sources of fluids. During the last decades, the diversity of fluid types with different nutritional composition has increased substantially. These fluids contribute to total intake more than water (e.g. energy, minerals, additives or caffeine), raising the question of their impact on health. In fact, an analysis of NHANES data has demonstrated differences in the risk of chronic kidney disease (CKD) depending on the type of beverages consumed. A low intake of plain water was associated with an increased risk of CKD [adjusted OR for low vs. high intake of plain water = 2.36 (95 % CI 1.10–5.06)], whilst, compared with the highest intake of beverages besides plain water, a low intake was not associated with an increased risk [5]. One explanation for the different health impact of consumption of different fluid types could be due to differences in energy and nutrient content. Recently, different health institutions and nutrition societies have raised concern regarding an excessive intake of energy coming from free sugars, especially present in sugar-sweetened beverages [6]. A metaanalysis of randomised trials and prospective cohort studies showed that among free-living people with ad libitum diets, the intake of free sugars was a determinant of body weight; however, intake was assessed from both food and beverages [7]. In respect of the consumption of sugar-sweetened beverages, there is a substantial scientific evidence relating the frequent intake of this type of beverages and an increased risk of weight gain [8–10], becoming overweight or obese [11–14], developing metabolic syndrome [15–18], type 2 diabetes [19] or other health problems [17, 20, 21] compared with non-regular consumers.

This can partly be explained, as described in some cross-sectional and intervention studies, by the observation that frequent consumers of sugar-sweetened beverages had higher total energy intake [22–24]. Given the current obesity pandemic and the estimation by the WHO that diabetes will be the 7th leading cause of death in 2030 [25], it seems relevant to evaluate the daily intake of the different fluid types and their contribution to energy and sugar intake.A recent systematic literature review by Özen et al. [26] reported the fluid intake of adults from 18 different countries. Unfortunately, only 50 % of the 38 surveys included in the review reported the intake of water [26]. In addition, inconsistencies in the study designs, dietary assessment methods used or classification of beverages and age categories limit the comparison of results between countries. Furthermore, most of the surveys designed were originated in the USA and Europe, and it is pertinent in order to have a better understanding of the TFI, types of beverages consumed, and energy and free sugar consumed from beverages to extend the geographical scope of such studies.

Therefore, the aim of the present analysis was: (a) to describe the intake of drinking water and all other type of beverages in adults from 13 countries in three continents including Latin America and Asia, (b) to report energy intake from beverages and (c) to assess the percentage of adults exceeding the WHO recommendations on free sugars intake.

Methods

Design and study population

The present analysis gathers original and published data collected in adults (≥18 years) by 13 different cross-sectional surveys. The surveys were conducted in Latin America (Mexico [27], Brazil and Argentina), Europe (Spain [28], France, UK [29], Germany, Poland and Turkey) and Asia (Iran [30], China [31], Indonesia and Japan). Data collection of the individual surveys was performed between 2008 and 2014 by public (Iranian National Nutrition and Food Technology Research Institute, NNFTRI; and Chinese Centre for Disease Control, CDC) and private organisations. The primary objective of these surveys was to assess the intake of drinking water and different types of beverages. A detailed analysis of the volume of TFI (sum of drinking water and beverages of all types) of these 13 surveys can be found elsewhere [32].

A random recruitment of participants was performed in each country either from a database of volunteers for population surveys, or via systematic door-to-door recruitment until the quotas for age, gender, region, habitat and/or socioeconomic characteristics in relation to the total country population were met.

Individuals working in company advertising, marketing, market research, the media, the manufacture, distribution and/or sale of water and all kind of beverages were excluded from participation as these individuals might be more aware of their intakes of fluids. Individuals who were not able to read and write in the language of the questionnaire were not eligible to participate in the survey. Having a specific diagnosed disease and/or following a medically prescribed diet were additional exclusion criteria in UK, Iran and China. The surveys in Argentina, Poland and Japan also excluded participants who had taken part in a survey about non-alcoholic drinks in the previous 6 months. Participants who did not complete the full 7 days of the fluid record, participants reporting a mean total daily fluid intake below 0.4 L/day or higher than 6 L/day or those who had participated in a market research study in the previous 6 months were excluded from the analysis. Pregnancy or lactation was not a specific exclusion in the most countries, except in Iran and China.

The effective sample size for the present analysis was 16,276 participants. Individuals who agreed to be part of the survey received detailed information about the survey's objectives, what was expected from them, and information about the study's provisions to preserve confidentiality, risks and benefits, and a clear explanation about their option to participate voluntarily or not in the study. After being given a fully informed description of the study, following the principles of informed consent, participants were asked for their oral approval to participate. No monetary incentive was offered for taking part in the study. All data were recorded anonymously. Therefore, participants included in the data set cannot be identified, either directly or through identifiers. The survey protocol of the unpublished surveys was reviewed and approved by the University of Arkansas Review Board (ref. 14-12-376).

Assessment of the different fluid types

Participants were provided with a 24-h fluid-specific record to collect information on their intake of all fluid types over 7 consecutive days. The 7-day fluid-specific record was presented in the official country language. In all countries except France, Germany and Japan, a paper version of this 7-day fluid-specific record was delivered and explained to the participants during an initial interview at home. After a period of 7 days, the fluid record was collected from the participant's home by the researcher and checked with the participant. In France, Germany and Japan, participants completed the 7-day fluid-specific record online. On the morning of the first day, these participants received an electronic reminder with written instructions on how to fill in the fluid record. Paper memory cards were made available to the participants so that they could make notes during the day and subsequently complete the fluid record online. Both the paper and online records had the same structure; the participants were asked the type of the beverage, the volume of the intake, whether the beverage was consumed hot or cold, the reason for the intake, and where and when it was consumed. The questionnaire also asked whether the fluid was consumed by itself or with some food, but did not record the food consumed. To assist the participants in estimating how much fluid was consumed, a photographic booklet of standard fluid containers supported the records. The 13 surveys all used this method to assess the fluid intake and were referred to as Liq.In7 (abbreviation of Liquid Intake over 7 days).

Classification of the fluid types

The fluids recorded were classified into: water (tap and bottled water); milk and milk derivatives; hot beverages (coffee, tea and other hot beverages); juices; regular sweetened beverages (RSB) (carbonated and non-carbonated soft drinks, energy drinks, sports drinks and other sugared soft drinks); diet beverages (diet carbonated soft drinks, diet non-carbonated soft drinks, other diet soft drinks); alcoholic drinks and other beverages. A more detailed classification can be found in supplementary Table 1 of this paper. TFI was defined as the sum of all these categories. In UK, Poland, Indonesia and Japan, the intake of diet beverages was very small, and therefore, they were during the first data treatment included in the RSB category. In Argentina, Iran and Indonesia, only non-alcoholic beverages were recorded. In Spain and France, no fluids were classified into the group “Other beverages”.

Assessment of anthropometric variables

Height in metres (m) and weight in kilograms (kg) were self-reported by participants, except in Poland, Iran and China where these variables were measured. The body mass index (BMI) was calculated (kg/m2). In Mexico, Brazil, Argentina, Indonesia and Japan, no anthropometric data were available.

Calculation of energy and sugar intake from fluids

Energy and sugar intake from different types of beverages was calculated using the updated USDA international food composition tables [33]. Because the quantity consumed of the types of beverages in the category “Other beverages” was very low and these fluids frequently had an unknown food composition, this category was disregarded for the energy and sugar analysis. The percentage of individuals consuming more than 10% of energy requirements as free sugar, as recommended by WHO, was calculated [6]. WHO strongly recommends the intake of free sugars to less than 10% of total energy intake and recently even suggested under conditions a further reduction in the intake of free sugars below 5% of total energy intake [6]. Total energy requirement could not be calculated due to missing data of participants' weight and height in some countries. Therefore, the food balance sheets from the Food and Agriculture Organisation (FAO) were consulted to retrieve the mean energy intake (kcal/capita/day) of the adult population of the countries included in this analysis, which is accepted for ecological studies [34]. This source, however, contained the mean energy intake for total population, not separated by gender. In order to assess the differences in adherence to the WHO recommendation on free sugar intake between genders, the theoretical recommended daily energy requirement published by the Institute of Medicine was used for total population, but not for each country [35].

Statistical analysis

Data are presented either as means and 95 % confidence intervals (CI) for continuous variables, or as numbers and percentages for dichotomous variables. The mean intakes are estimated values of all participants, including non-consumers. We compared the distribution of the selected characteristics between groups Student's t tests for continuous variables. All statistical tests were two-tailed, and the significance level was set at $P < 0.05$. A Bonferroni post hoc test was used to correct for multiple comparisons in the online resources 2 and 3. All analyses were performed using the SPSS software version 22.0 (SPSS Inc., Chicago, IL).

Results

The daily water and beverages intake of 16,276 participants (47 % men) of 13 countries was analysed in the present study. The baseline characteristics of the male and female participants are presented in Table 1. The mean age of the male and female participants was 40.6 (40.3, 40.9) and 39.2 (38.9, 39.5) years, respectively. The mean BMI of the male and female participants was 25.6 (25.4, 25.7) and 25.0 (24.8, 25.1) kg/m2, respectively.

The daily intakes of the different beverage types are presented in Table 2. Among the different fluid types, the higest volumes were observed for water intake, which ranged from 0.27 L/day in Japan to 1.78 L/day in Indonesia. The second type of fluid consumed in terms of volume was hot beverages, with a daily intake ranging from 0.12 L/day in Mexico to 1.03 L/day in UK. RSB was the third mostly fluid consumed with a daily intake ranging from 0.10 L/day in China to 0.57 L/day in Mexico.

Significant gender differences were inconsistently observed across countries for the daily intake of different types of beverages (supplementary Table 2). Water intake was significantly higher among women than men in Germany, Turkey and the total sample, whereas water intake was lower among women than men in Brazil. Women had a significantly higher milk intake then men in Brazil, Germany and the total sample. A higher intake among women than men was also observed for hot beverages in Mexico, Spain, France and Poland. The significant difference in RSB intake between genders was also inconsistent across countries. In Brazil, Spain and Germany, women consumed less RSB than men, whereas in France and China women consumed more RSB than men. The significant gender effect on diet beverages was consistent, yet only present in two countries: women consumed more diet beverages then men in Spain and France. The mean intake of alcoholic beverages was significantly higher among men than women in Mexico, Brazil, Spain, France, Germany, Poland and the total sample. Figure 1 represents the contribution (%) of the different fluid types to TFI. Countries with similar contribution patterns can be identified. Indonesia, China, Spain, Iran, Turkey and France are countries with the largest contribution of water to TFI, ranging from 47 to 78 %. The second largest contributor to TFI, in all these countries, was hot beverages. A different pattern was observed in Mexico and Brazil. In these countries, the contribution of RSB and juices to TFI was as large as the water contribution to TFI. This was also the case of Argentina, where the contribution of juices and RSB is larger than the water contribution; however, hot beverages are the primary contributor to TFI in this country. A high contribution of hot beverages to TFI was also observed among Germany, Poland and UK. However, unlike in Argentina, the contribution of water to TFI was larger than the contribution of RSB and juices. The contribution of water, juices, RSB and alcoholic beverages to TFI was comparable in these three countries (Germany, Poland and UK). The largest contribution of hot beverages (50 %) and alcoholic beverages (14 %) to TFI was observed in Japan.

Table 3 shows the mean energy intake from fluids. Total mean energy intake of total fluid ranged from a minimum of 182 kcal/day in Indonesia to a maximum of 817 kcal/day in Germany. In the total sample, the highest mean energy intake came from the consumption of milk and derivatives, followed by alcoholic beverages and then hot beverages. In Germany, Brazil, Iran, China and Spain, the milk and derivatives consumption represented the highest energy intake of all fluid types (299, 220, 182, 110 and 108 kcal/day, respectively). In France and Japan, the highest energy intake came from alcoholic beverages (95 and 159 kcal/day, respectively), whereas in UK, Poland and Turkey, hot beverages delivered the highest energy intake (205, 146 and 102 kcal/day, respectively). In Mexico and Indonesia, the highest energy intake from fluids came from RSB (232 and 74 kcal/day, respectively). Significant gender difference in energy intake provided by the different fluid types was also observed (Supplementary Table 3). In the total sample, men had a significantly higher mean energy intake from RSB and alcoholic beverages than women. Women on the other hand had a higher

Table 1. *General characteristics of the study population, categorised by country and gender*

	n (%)	Age (years)	Age categories (years, %)				Weight (kg)	Height (m)	BMI (kg/m²)
			18–29	30–39	40–49	≥ 50			
Mexico, 2012									
Men	574 (38)	38.6 (37.4, 40.0)	35.5	18.3	17.2	28.9	ND	ND	ND
Woman	924 (62)	38.3 (37.5, 39.2)	33.0	22.3	21.0	23.7	ND	ND	ND
Brazil, 2008									
Men	941 (49)	34.5 (33.8, 35.2)	39.5	25.3	25.4	9.8	ND	ND	ND
Woman	983 (51)	34.7 (34.0, 35.4)	36.8	27.7	25.5	10.0	ND	ND	ND
Argentina, 2009									
Men	241 (47)	37.1 (35.3, 38.8)	38.6	21.6	18.3	21.6	ND	ND	ND
Woman	266 (56)	37.8 (36.2, 39.4)	36.5	20.7	17.3	25.6	ND	ND	ND
Spain, 2012									
Men	630 (51)	42.9 (41.8, 44.0)	18.6	25.4	23.3	32.7	78.8 (77.8, 79.8)	1.7 (1.7, 1.7)	26.1 (25.8, 26.4)
Woman	610 (49)	43.0 (41.9, 44.1)	19.5	21.5	26.2	32.8	65.2 (64.3, 66.1)	1.6 (1.6, 1.6)	25.1 (24.7, 25.4)
France, 2012									
Men	804 (52)	47.6 (46.5, 48.6)	15.7	16.8	18.4	49.1	80.5 (79.6, 81.5)	1.7 (1.7, 1.8)	26.1 (25.8, 26.4)
Woman	730 (48)	41.5 (40.5, 42.5)	22.2	23.2	24.5	30.1	65.5 (64.4, 66.6)	1.6 (1.6, 1.6)	24.2 (23.8, 24.6)
UK, 2010									
Men	371 (41)	46.3 (44.7, 47.9)	16.7	20.8	20.2	42.3	ND	ND	28.8 (28.2, 29.5)
Woman	526 (59)	42.2 (41.0, 43.4)	19.6	26.4	25.3	28.7	ND	ND	25.9 (25.3, 26.5)
Germany, 2012									
Men	856 (45)	44.1 (43.2, 44.9)	16.4	20.1	26.5	37.0	81.6 (80.3, 82.8)	1.8 (1.8, 1.8)	25.8 (25.4, 26.2)
Woman	1012 (54)	41.9 (41.2, 42.7)	17.5	22.3	30.6	29.5	77.0 (75.9, 78.2)	1.7 (1.7, 1.7)	27.3 (26.8, 27.7)
Poland, 2014									
Men	517 (49)	46.0 (44.5, 47.4)	19.5	19.0	19.1	42.4	82.8 (81.6, 84.0)	1.8 (1.7, 1.8)	26.6 (26.3, 27.0)
Woman	545 (51)	46.2 (44.8, 47.6)	19.4	20.7	16.5	43.3	70.1 (68.9, 71.3)	1.6 (1.6, 1.7)	25.5 (25.1, 25.9)
Turkey, 2011									
Men	488 (51)	34.4 (33.4, 35.3)	37.7	27.3	24.2	10.9	75.9 (74.8, 77.0)	1.7 (1.7, 1.7)	25.0 (24.7, 25.4)
Woman	473 (49)	34.3 (33.4, 35.3)	38.5	27.9	22.6	11.0	65.8 (64.6, 67.1)	1.6 (1.6, 1.6)	25.0 (24.5, 25.5)
Iran, 2011									
Men	283 (49)	37.3 (35.8, 38.8)	36.7	24.0	19.4	19.8	79.3 (77.7, 81.0)	1.7 (1.7, 1.8)	25.8 (25.3, 26.2)
Woman	289 (51)	36.5 (35.1, 37.9)	35.3	28.0	20.1	16.6	63.9 (62.6, 65.3)	1.6 (1.6, 1.6)	24.9 (24.3, 25.4)
China, 2010									
Men	733 (50)	39.5 (38.6, 40.4)	24.7	25.2	25.8	24.3	67.4 (66.6, 68.2)	1.7 (1.7, 1.7)	23.2 (23.0, 23.5)
Woman	733 (50)	39.3 (38.5, 40.2)	24.7	25.6	25.8	23.9	55.9 (55.3, 56.5)	1.6 (1.6, 1.6)	22.1 (21.9, 22.3)
Indonesia, 2012									
Men	444 (32)	35.5 (34.3, 36.7)	39.4	25.7	16.9	18.0	ND	ND	ND
Woman	922 (68)	35.1 (34.4, 35.8)	39.3	28.5	17.6	14.6	ND	ND	ND
Japan, 2009									
Men	698 (51)	ND	26.6	27.4	21.5	24.5	ND	ND	ND
Woman	683 (49)	ND	26.1	27.1	21.1	25.8	ND	ND	ND
Total population[a]									
Men	7580 (47)	40.6 (40.3, 40.9)	27.0	22.8	22.0	28.3	77.9 (77.5, 78.4)	1.7 (1.7, 1.7)	25.6 (25.4, 25.7)
Woman	8696 (53)	39.2 (38.9, 39.5)	28.0	24.8	23.3	23.9	67.0 (66.6, 67.5)	1.6 (1.6, 1.6)	25.0 (24.8, 25.1)

Data expressed as mean (95% CI) or percentage
BMI body mass index, ND no data
[a]Include only those countries with data available on the presented characteristics

Table 2. *Total daily consumption of different types of beverages (L/day) for total population*

	Water	Milk and derivates	Hot beverages	Juices	Regular sweetened beverages	Diet beverages	Alcoholic bever-ages	Other beverages	Total fluid intake
Mexico (n = 1498)	0.70 (0.66, 0.73)	0.19 (0.18, 0.20)	0.12 (0.11, 0.13)	0.18 (0.16, 0.19)	0.57 (0.54, 0.59)	0.02 (0.01, 0.02)	0.03 (0.02, 0.04)	0.00 (0.00, 0.00)	1.81 (1.76, 1.86)
Brazil (n=1924)	0.83 (0.80, 0.86)	0.21 (0.20, 0.22)	0.31 (0.28, 0.33)	0.48 (0.46, 0.50)	0.23 (0.21, 0.24)	0.01 (0.00, 0.01)	0.15 (0.13, 0.17)	0.00 (0.00, 0.01)	2.22 (2.17, 2.27)
Argentina (n=507)	0.39 (0.35, 0.43)	0.16 (0.15, 0.18)	0.92 (0.86, 0.98)	0.27 (0.24, 0.31)	0.37 (0.31, 0.42)	0.19 (0.16, 0.22)	ND	0.00 (0.00, 0.00)	2.30 (2.22, 2.39)
Spain (n = 1240)	1.01 (0.97, 1.05)	0.10 (0.09, 0.11)	0.30 (0.29, 0.32)	0.09 (0.08, 0.10)	0.16 (0.14, 0.17)	0.04 (0.03, 0.05)	0.20 (0.18, 0.22)	ND	1.90 (1.86, 1.95)
France (n = 1534)	0.76 (0.73, 0.78)	0.06 (0.06, 0.07)	0.39 (0.37, 0.41)	0.06 (0.06, 0.06)	0.12 (0.11, 0.13)	0.03 (0.02, 0.03)	0.13 (0.12, 0.14)	ND	1.56 (1.52, 1.59)
UK (n = 897)	0.51 (0.46, 0.55)	0.09 (0.08, 1.00)	1.03 (0.98, 1.07)	0.12 (0.1, 0.13)	0.37 (0.33, 0.40)	ND [a]	0.20 (0.18, 0.22)	0.00 (0.00, 0.01)	2.32 (2.26, 2.37)
Germany (n = 1868)	0.79 (0.75, 0.82)	0.29 (0.27, 0.31)	0.69 (0.66, 0.72)	0.18 (0.17, 0.20)	0.26 (0.24, 0.28)	0.01 (0.01, 0.01)	0.25 (0.23, 0.26)	0.01 (0.01, 0.01)	2.47 (2.43, 2.52)
Poland (n = 1062)	0.46 (0.44, 0.48)	0.08 (0.07, 0.09)	0.73 (0.71, 0.75)	0.09 (0.08, 0.10)	0.17 (0.15, 0.18)	ND [a]	0.10 (0.09, 0.11)	0.01 (0.00, 0.01)	1.64 (1.60, 1.67)
Turkey (n = 961)	1.04 (1.00, 1.09)	0.06 (0.05, 0.07)	0.51 (0.48, 0.54)	0.12 (0.11, 0.14)	0.20 (0.18, 0.22)	0.00 (0.00, 0.00)	0.01 (0.01, 0.02)	0.25 (0.23, 0.27)	2.21 (2.15, 2.27)
Iran (n = 572)	0.96 (0.91, 1.02)	0.17 (0.16, 0.19)	0.51 (0.48, 0.53)	0.07 (0.06, 0.07)	0.13 (0.11, 0.14)	0.01 (0.01, 0.02)	ND	0.07 (0.06, 0.08)	1.92 (1.86, 1.99)
China (n = 1466)	0.96 (0.92, 0.99)	0.10 (0.10, 0.11)	0.45 (0.42, 0.49)	0.02 (0.02, 0.02)	0.10 (0.09, 0.11)	ND [a]	0.09 (0.08, 0.10)	0.03 (0.03, 0.03)	1.76 (1.71, 1.81)
Indonesia (n = 1366)	1.78 (1.73, 1.84)	0.05 (0.04, 0.05)	0.26 (0.24, 0.27)	0.02 (0.01, 0.02)	0.17 (0.15, 0.20)	ND [a]	ND	0.01 (0.01, 0.02)	2.28 (2.23, 2.34)
Japan (n = 1381)	0.27 (0.25, 0.29)	0.08 (0.07, 0.09)	0.75 (0.73, 0.78)	0.06 (0.05, 0.06)	0.11 (0.10, 0.11)	ND [a]	0.21 (0.19, 0.23)	0.01 (0.01, 0.02)	1.50 (1.46, 1.53)
Total population (n = 16,276)	0.82 (0.81, 0.84)	0.13 (0.13, 0.14)	0.49 (0.49, 0.50)	0.14 (0.14, 0.15)	0.22 (0.21, 0.22)	0.02 (0.02, 0.02)	0.12 (0.12, 0.12)	0.02 (0.02, 0.02)	1.98 (1.96, 1.99)

Data expressed as mean (95% CI)

ND no data

[a]In case of UK, Poland, China, Indonesia and Japan, the intake of diet beverages was included in the regular sweetened beverages category

Table 3.*Energy intake (in kcal) of different types of fluid intake by country and total population*

	Milk and derivates	Hot beverages	Juices	Regular sweetened beverages	Diet beverages	Alcoholic beverages	Total fluid intake
Mexico (n = 1498)	200 (189, 211)	25 (23, 27)	80 (74, 86)	232 (220, 243)	3 (2, 3)	25 (19, 30)	565 (547, 583)
Brazil (n = 1924)	220 (208, 232)	62 (57, 66)	216 (207, 225)	82 (76, 89)	1 (1, 1)	113 (98, 129)	694 (672, 716)
Argentina (n = 507)	168 (153, 183)	184 (172, 197)	123 (108, 139)	147 (124, 170)	27 (23, 31)	ND	649 (622, 676)
Spain (n = 1240)	108 (96, 119)	61 (58, 64)	42 (38, 47)	63 (56, 69)	5 (4, 7)	149 (135, 164)	428 (408, 447)
France (n = 1534)	66 (59, 73)	78 (75, 82)	27 (25, 29)	52 (48, 57)	4 (3, 5)	95 (87, 103)	329 (318, 340)
UK (n = 897)	98 (86, 110)	205 (196, 215)	54 (48, 60)	151 (138, 164)	ND [a]	148 (132, 164)	656 (633, 679)
Germany (n = 1868)	299 (279, 318)	138 (133, 143)	81 (75, 88)	108 (100, 116)	2 (1, 2)	187 (174, 199)	817 (792, 842)
Poland (n=1062)	83 (76, 91)	146 (142, 150)	41 (38, 45)	70 (65, 76)	ND [a]	76 (68, 84)	415 (401, 428)
Turkey (n = 961)	65 (56, 74)	102 (97, 107)	55 (48, 62)	85 (77, 94)	0 (0, 1)	8 (5, 12)	314 (298, 330)
Iran (n = 572)	182 (167, 196)	102 (97, 107)	29 (26, 32)	50 (44, 56)	2 (1, 2)	ND	365 (347, 383)
China (n = 1466)	110 (103, 117)	91 (83, 98)	9 (8, 11)	41 (36, 45)	ND [a]	69 (59, 79)	320 (305, 336)
Indonesia (n = 1366)	48 (41, 54)	52 (48, 55)	8 (6, 9)	74 (64, 84)	ND [a]	ND	182 (170, 194)
Japan (n = 1381)	84 (77, 90)	151 (146, 155)	26 (24, 29)	40 (36, 44)	ND [a]	159 (146, 172)	460 (444, 475)
Total population (n = 16,276)	140 (137, 144)	99 (97, 101)	64 (62, 66)	91 (88, 93)	2 (2, 3)	91 (87, 94)	490 (483, 496)

Data expressed as mean (95 % CI)

ND no data

[a] In case of UK, Poland, China, Indonesia and Japan, the intake of diet beverages was included in the regular sweetened beverages category

energy intake provided by milk and derivatives than men.

Figure 2 shows the proportion of participants exceeding the WHO recommendation on energy intake provided by free sugar, solely by the intake of fluids. The highest proportion of adults exceeding the WHO recommendation was observed in Germany (70.9 %), followed by Brazil (65.7 %), Mexico (65.1 %), UK (61.5 %) and Argentina (60.4 %), whereas the lowest proportion was observed in Indonesia (10.9 %). Considering all countries together, 44.5 % of the population exceeded the WHO recommendations on energy intake provided by free sugar, solely by fluids.

Discussion

The aim of the present analysis was to collate and describe the intake of water and all other fluids of adults of 13 cross-sectional surveys, which used the same 7-day fluid-specific record. This unique compilation of national surveys conducted in large sample of participants from different countries demonstrated that not only the volume, but also the contribution of the different fluid types to TFI varied substantially between countries. Nevertheless, some countries that seemed to be geographically linked share similar patterns. The fluid intake of the countries relatively close to the

Fig. 1. *Contribution of the different types of beverages to TFI stratified by country*

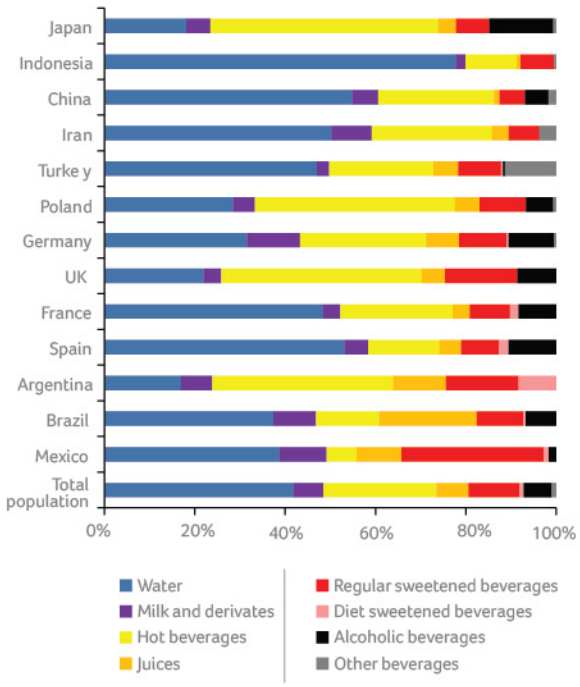
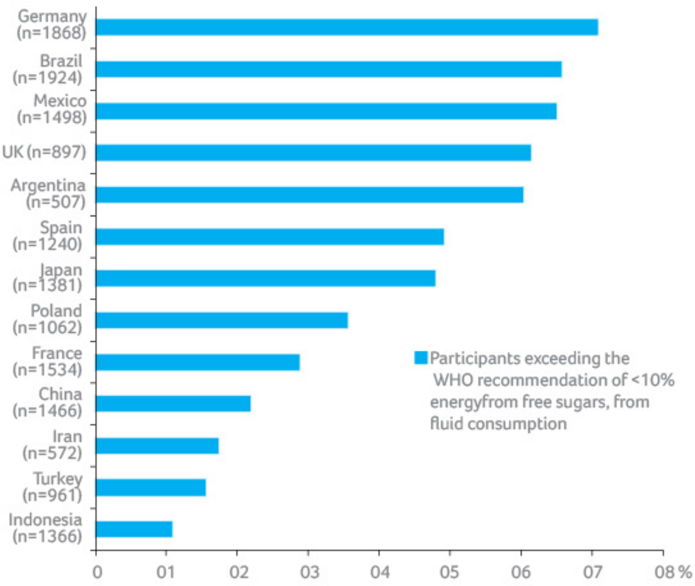


Fig. 2. *Participants exceeding WHO recommendations for free sugar (<10 % of energy), considering only fluid intake*



Mediterranean Sea (Spain, France, Turkey and Iran) and also the two Asian countries (Indonesia and China) was characterised by a high contribution of water to TFI, ranging from 47 to 78 %. In North European countries (UK, Poland and Germany), the highest contribution to TFI came from hot beverages. The fluid intake of the three countries of Latin America was characterised by a high contribution of juices and RSB, which is as important as the contribution of water to TFI. Due to these substantial intergeographical area differences in fluid intake contribution, the pooled data of all countries should be interpreted with caution. Identifying factors that could explain these observed between-country differences was not the aim of the current analysis, yet several hypotheses can be made. One of the possible factors explaining the between-country differences is climate and seasonality. Studies analysing seasonality of fluid intake indicated that temperature and seasons affected both volume and choice of beverages type [36]. However, Tani et al. [37] reported that in China an increase of 1 °C in the mean outdoor air temperature on the survey day was associated with an increased intake of water from fluids by only 8.4 mL/day ($P < 0.0001$) and that the influence of humidity was non-significant. Therefore, it seems unlikely that the differences observed between countries in volumes of beverage can be explained by climate alone. The impact of seasonality on the reported fluid intake between countries cannot be evaluated in this study, because in each survey data collection took place once during a period of the year with a mild climate (spring or autumn). Other factors to take into consideration when assessing the between-country variability are cultural and traditional habits, which unfortunately were not evaluated in the present study.

The data in the current analysis are in line with data reported in other published surveys. The fluid intake pattern with a high contribution of water to TFI characteristically for the Mediterranean countries was also reported in France by Bellisle et al. [39] and in Italy by Leclercq et al. [38]. Even though Bellisle et al. [39] reported a lower TFI and a higher intake of milk and alcoholic beverages in French adults than observed in our French survey, a pattern characterised by a relatively high contribution of water (43 %) and hot beverages (20 %) was also observed. Furthermore, a high contribution of water to TFI (58 % in men and 67 % in women) was also observed among Italian adults [38]. Although Italy was not included in the current analysis, this beverage pattern was similar than that we observed among the countries relatively close to the Mediterranean Sea.

The intake of the North European countries in the current surveys was characterised by a high intake of hot beverages. The National Nutritional Survey II assessed food intake of 15,371 German adults confirmed a similar contribution of hot beverages (21 %) to TFI, even though they reported higher volumes of all fluid types and a higher contribution of water to TFI (42 vs. 32 % in the present study) than in the current analysis. The contribution of juices and RSB to TFI observed in the present analysis was also different compared with others surveys [40]. These differences can be explained in part because in the present study these fluid types were split; however, the combined contribution (juices plus RSB) of 20 % is comparable to the 17 % observed in previous studies. For the UK, two previously published surveys reported TFI volumes and energy intake provided by beverages among adults that were in line with our observations [22, 41]. A survey performed in another North European country not included in the current analysis, Finland, also showed a fluid intake pattern characterised by a high contribution of water (34 and 51 % for men and women, respectively) and hot beverages (39 and 37 % for men and women, respectively) to TFI [42].

In Latin American countries, publications reporting fluid intake in adults were mainly focussed on the intake of caloric beverages and covered only the Mexican population [43, 44]. These two Mexican surveys described volumes of intake for the different fluid categories comparable to those in the current analysis. However, in both studies mean energy intake from fluids (372 and 382 kcal/day/per capita, respectively) was estimated to be lower than that estimated in the present study, which could be probably explained by a different classification

of the beverages and the use of different food composition data.
The results obtained in the present international survey highlight the need to educate adults about the nutritional composition of the different fluids. As observed in previous studies, an accurate education programme and public health actions would be effective to encourage regular consumers to decrease their RSB consumption with water or other non-caloric beverages, in order to decrease the risk of chronic disease such as type 2 diabetes [23, 45] or overweight/obesity [7]. Attention should also be paid to fruit juices, because adult individuals still perceive beverages such as squashes, fruit lemonades and fruit sodas as a healthy option, and they should be advised about the low fruit content and the higher amounts of sugar [46]. In this present analysis, juices and RSB were separated into two different categories, because the nutritional composition is different. 100 % fruit juices could potentially contribute to daily vitamin and antioxidants intake [47]. However, regarding sugar content, RSB and juices are comparable; therefore, an increased intake should not be encouraged.
Several limitations of the fluid surveys or the current analysis need to be discussed. As often happens in nutritional research, the self-reported surveys collecting the intake of fluids are open to potential bias due to the over- or under-reporting of certain fluid types. This limitation can also be related to the current analysis, even though the same 7-day fluid-specific record was used in all the surveys. Another limitation was that the classification of diet beverages was not performed in the same way in all countries and alcoholic beverages were not recorded in some surveys, which limited the comparison between countries. Sugar and energy content per 100 mL of fluid type was used for the estimation of the energy and sugar consumed from each beverage in all countries. These were an approximate estimation of the reality, since the same fluid type of the same brand can have a different nutritional composition depending on the country. Additionally, sugar or other ingredients added by the consumer to the fluids were not taken into account for the calculation of energy intake. Therefore, the energy intake from fluids is likely to be underestimated. For the evaluation of the percentage of energy provided by free sugar, total energy intake had to be estimated since no food data were collected. The lack of food data also limited the interpretation of the data on energy intake from fluids. However, evidence suggested that a fluid-specific record might more accurately estimate fluid intake compared with a food and fluid record [48]. Since the primary aim of all 13 surveys included was to assess fluid intake, the preference was given to record fluids only. Due to the lack of anthropometric data of the participants in certain countries, the calculations had to be based on population means of energy intake. Nevertheless, this assumption was considered to be acceptable in epide-miological studies since the individual surveys aimed at collecting data from a nationally large sample of individuals and also because the energy intake data for the food balance sheets were recorded during the same year of the fluid surveys. Despite these methodological limitations, this analysis has several strengths. This analysis is unique as it collated data of 13 surveys with relatively large sample sizes and an equal distribution between both genders. The compilation also contains original data from countries, which previously had no internally published fluid intake data available. The third strength is the use of the same 7-day fluid-specific diary in all the surveys that was also supported by a photographic booklet to limit the self-reporting error. Finally, the intake of drinking water and all other fluids were reported, in the 13 surveys except alcoholic beverages in three countries. This is rather exceptional as shown in the systematic review by Özen et al. [26].
In conclusion, the current study shows that intake volumes of the different fluid types differ considerably between countries, but these differences in the contribution to TFI are modest between countries of the same geographical area. Even though the highest volume consumed was recorded for drinking water, the mean energy intake from fluids was higher than expected due to the high consumption of RSB and fruit juices (reached up to 694 kcal/day of energy intake on average). Since the proportion of adults exceeding the WHO recommendation for energy intake provided by free sugars ranged from 11 up to 70.9 %, educating adults about the nutritional composition of the different fluids seems a pertinent step but not only one in terms of public health. Health authorities and food industry should take complementary actions to promote fluids with low sugar content and to create an environment favouring water consumption.

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Conflict of interest
IG is an employee of Danone Research. JS-S, JS, LAM, SK, JG, HM are members of advisory board on fluid intake of Danone Research. S.A.K. has received research grants from Danone Research. B.S. has received research grant from R&D AQUA Group, Indonesia. A.M and N.E. are employer at NNFTRI, an instituted which has received a research grant from Damavand mineral water company (a brand of Danone Group in Iran). J.S.-S. and N.B. have received consultancies from Danone S.A. C.F.-P. and J.A. report no conflict of interest.

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TOTAL FLUID INTAKE OF CHILDREN AND ADOLESCENTS: CROSS-SECTIONAL SURVEYS IN 13 COUNTRIES WORLDWIDE

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Abstract

Purpose

To describe total fluid intake (TFI) according to socio-demographic characteristics in children and adolescents worldwide.

Methods

Data of 3611 children (4–9 years) and 8109 adolescents (10–18 years) were retrieved from 13 cross-sectional surveys (47 % males). In three countries, school classes were randomly recruited with stratified cluster sampling design. In the other countries, participants were randomly recruited based on a quota method. TFI (drinking water and beverages of all kinds) was obtained with a fluid-specific record over 7 consecutive days. Adequacy was assessed by comparing TFI to 80 % of adequate intake (AI) for total water intake set by European Food Safety Authority. Data on height, weight and socioeconomic level were collected in most countries.

Results

The mean (SD) TFI ranged from [1.32 (0.68)] to [1.35 (0.71)] L/day. Non-adherence to AIs for fluids ranged from 10 % (Uruguay) to >90 % (Belgium). Females were more likely to meet the AIs for fluids than males (4–9 years: 28 %, OR 0.72, $p = 0.002$; 10–18 years: 20 %, OR 0.80, $p = 0.001$), while adolescents were less likely to meet the AI than children (OR 1.645, $p < 0.001$ in males and OR 1.625, $p < 0.001$ in females).

Conclusions

A high proportion of children and adolescents are at risk of an inadequate fluid intake. This risk is especially high in males and adolescents when compared with females or children categories. This highlights water intake among young populations as an issue of global concern.

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Introduction

Water is essential for life to the extent that hydration is a major key to survival [24]. This is especially true for infants and adolescents who have relatively high requirements for water to maintain an adequate body composition [28]. This high requirement can partially be explained because children have proportionally higher body water content than adults [5]. Besides the higher body water content, body surface area to body mass ratio is higher in children when compared with adults. This difference levels out by adolescence, when children have almost reached their adult size [27]. At this time, gender differences start to appear: females store more adipose tissue than males and therefore water percentages are lower than in males [1].

Dehydration (body water deficit) is a physiologic state that can have profound implications for human health [10]. Under conditions of severe dehydration, a decreased sympathetic nervous activity, impaired thermoregulation and impaired cognitive and physical performance can be observed [29]. In children, even mild dehydration can affect cognitive school performance [16, 17].

International organizations have set dietary reference intakes (DRIs) for total water in young populations, using different methodologies. For instance, in children between the ages of 4 and 13, the European Food Safety Authority (EFSA) based its DRIs primarily upon energy intake, while for adolescents aged 14 years through to adulthood, intake reference values are based on population median water consumption and desirable urine osmolality [1]. The Institute of Medicine (IOM) DRIs for total water intake in the USA and Canada are the median intakes observed in the National Health and Nutrition Examination Survey III (NHANES), for children aged 1–18 years as well as for adults [2]. Due to such differences in methods for the derivation of reference values, health authorities stress the necessity to establish the water intake recommendations based on water balance [1].

Despite the availability of intake reference values specific for children and adolescents, little is known about the adherence to these recommendations in these age groups. The limited data available suggest that children and adolescents do not drink enough and do not meet the daily recommended fluid intake. Total fluid intake (TFI) is set as the sum of liquids provided by all types of fluids or beverages, and it is assumed to be around 80 % of all the water intakes (20 % from foods) [1]. A German longitudinal study conducted in children and adolescents reported a mean total water intake of 1642 and 1457 ml in 9–13-year-old males and females, respectively [4]. This is approximately 450 ml lower than the corresponding EFSA reference values of 2100 (males) and 1900 ml (females) [26]. A similar situation was observed in European adolescents, as their mean total water intake was 1611 and 1316 ml in 12.5–17.5-year-old males and females, respectively [15]. In US children and adolescents, 4–19 years in the NHANES survey 2005–2006, mean daily total water intake was lower than the IOM adequate intake (AI) (only 15–35% met the recommendations according to sex and age groups) [21]. In a Brazilian study [18], in which no statistically significant differences were observed between males and females, TFI was higher than that observed in the previously cited studies, being approximately 1750 ml for children and 2050 ml for adolescents.

The aim of the present study is to describe fluid intake and its variation by age (children 4–9 years vs. adolescents 10–18 years) and/or sex in 13 countries worldwide controlling for BMI and socioeconomic status.

Methods

Design and study population

Cross-sectional surveys were identified from 13 different countries to summarize country-specific TFI of participants aged 4–18 years. The surveys (whose aim was to systemati-cally obtain a complete set of data from fluid intake) were conducted during one period of the year in Latin America (Mexico, Brazil, Argentina, Uruguay), Europe (Spain, France, Belgium, UK, Poland, Turkey) and Asia (Iran, China, Indonesia) by private research organizations, the Université libre de Bruxelles/the Club Européen des Diététiciens de l'Enfance (CEDE), the Iranian National Nutrition & Food Technology Research Institute (NNFTRI) and the Chinese Center for Disease Control (CDC). The individual surveys took place between 2008 and 2014 (Online Resource 1).

The protocol of the published surveys was described in detail elsewhere [13, 14, 25], but will again briefly be described. The surveys performed in Belgium, Iran and China had a comparable method of recruitment: they recruited entire school classes via a random, stratified cluster sampling. In Belgium, 13 schools had accepted to participate, and in each school, the classes of the third- up to the sixth-grade participated [25]. In Iran, the recruitment was performed in Tehran. To cover all SES groups, Tehran was divided into three major areas: north, middle and south, representing high, middle and low SES, respectively. Eighteen schools were randomly selected to cover three school levels and two genders in every area. In selected schools, one class was randomly selected from each grade (except for the first and 12th grades). All of the students of a class were recruited. In China, a multi-stage random sampling method is adopted throughout the survey [13, 14]. The parents of the recruited school children were informed via meetings, written information sheets or phone calls. The surveys performed in the 10 other countries randomly recruited participants using a quota-based method with quotas set for age, gender, region of the country, habitat and/or socioeconomic characteristics. The parents of the children were contacted via a database of individuals volunteering for population surveys or via a systematic door-to-door approach, with an invitation for their child to participate. Having a parent working in advertising, marketing, market research, media or manufacture, distribution and sale of beverages (in order to have participants that were not specifically aware of their fluid intake) and being incapable of completing the questionnaire in the language presented were exclusion criteria. Having a specific diagnosed disease and/or following a medically prescribed diet were additional exclusion criteria (to avoid individuals that might have modified their usual fluid intake) in the surveys of UK and China. The surveys in Argentina, Poland and Japan also excluded participants who took part in a survey about non-alcoholic drinks in the last 6 months.

All parents and children willing to participate (those who did not were not tracked) in the survey received detailed information about the survey objectives, what was expected from them, as well as a disclosure of the survey's provisions to preserve confidentiality, risks and benefits, and a clear explanation about their option to voluntarily participate or not in the survey. After offering a full-informed description of the survey, parents were asked for their oral approval to let their child participate. No monetary incentive was offered for taking part in the survey. All data were recorded in an anonymous way. Therefore, participants cannot be identified, directly or through identifiers linked to the participants. The protocol of the unpublished surveys was reviewed and approved by the Institutional Review Board, Office of Research Compliance of the University of Arkansas (IRB Protocol # 14-12-376).

Assessment of fluid intake

A fluid-specific record over 7 consecutive days was completed by the participants. These 7-day fluid-specific records and the associated written information were presented to the participants in the official language of the country and were in a paper format, except in France where the fluid records were completed online. This online fluid-specific record, which had the same structure as the paper version, was supported with paper memory cards to make notes throughout the day. An investigator delivered and explained the fluid record to the participants during a face-to-face interview at home. For children below 12 years, the primary caregiver of the child was asked to complete the fluid records. The researcher visited the home again after 7 days to collect the fluid-specific records and to ensure their completion. The surveys performed in Belgium, Iran and China deviated from this protocol as they recruited children in school classes [3, 5]. In these cases, both parents and teachers were involved in the completion of the fluid records.

The 7-day fluid-specific records in all surveys were structured in the same way in order to capture the type of fluid consumed, the volume of intake, the reasons, the moment of the day and the place of all fluid intakes. To assist the participants in estimating the consumed volumes, the records were supported by a photographic booklet of standard containers of fluids and in China by an additional scaled water container. The sum of all fluid types recorded was defined as TFI. To evaluate the adequacy of fluid intake, the EFSA age- and gender-specific reference values for total water intake were used in order not to overestimate the size of the problem of inadequate fluid intake (in comparison with other reference values), after extracting 20% supposed to correspond to water intake from foods [1]. Consequently the reference values of 1.3, 1.7 and 2 L/day were used for males aged 4–8, 9–13 and 14–18 years, respectively. The reference values of 1.3, 1.5 and 1.6 L/day were used for females aged 4–8, 9–13 and 14–18 years respectively. These values will be referred to as EFSA AIs for fluids. However, the presentation of the results throughout the paper will be done only by children and adolescents, but fitting them in their corresponding reference value for water intake recommendations.

Assessment of body composition and socio-economical level

Body mass index (BMI) serves as a proxy for both low physical activity and poor health status, two key determinants of water requirements. Height in metres (m) and weight in kilograms (kg) were self-reported in the surveys in Spain, France, UK and Turkey and measured by the investigator in the surveys in Belgium, Poland, Iran and China. No anthropometric data were collected in Mexico, Brazil, Uruguay, Argentina and Indonesia. Body mass index (BMI) was calculated (kg/m2) and categorized using the International Obesity Task Force cut-off points [8, 9]. These cut-off points were established according to thinness, sex and age (i.e. male, 8 years, BMI 14.14 kg/m^2 or lower = underweight; male, 8 years, BMI = 14.15–18.43 kg/m^2 = normal weight; male, 8 years, BMI = 18.44–21.59 kg/m^2 = overweight; male, 8 years, BMI = 21.60 kg/m^2 or higher = obesity). Socioeconomic level (SEL) was assessed using a self-administered questionnaire in most of the countries and was categorized using the Market Research Society classification. This classification was based on the occupation of the chief income earner in the household [3, 12].

Statistical analysis

Participants who did not complete the full 7-day fluid intake records or participants reporting a mean total daily fluid intake below 0.4 L/day or higher than 4 L/day were excluded from the analysis. The final sample size for this analysis was 11720 participants. Continuous and categorical data were, respectively, presented as mean (SD) and/or median (25th–75th percentile) and percentage (n). Standard error of the mean (SEM) and additional percentiles (5th, 10th, 90th, 95th) are reported in Online Resource 2. The effect of gender on the non-adherence to AIs for total water intake was tested with Chi-square test stratified by country.

Associations between compliance with AIs for fluids by gender and age group were assessed by logistic regression analysis (Fig. 2) stratifying the results by country. To estimate the strength of the association, odds ratios and 95 % confidence intervals (CI) were assessed using age- or gender-stratified forest plots. The models were adjusted for gender, BMI and SEL. Males were considered as reference in the first model (Fig. 2). Indonesia, Mexico, Argentina, Brazil and Uruguay were excluded from the logistic regression analysis due to the lack of data for some covariates. Analyses were performed using SPSS software version 20.0 (SPSS Inc, Chicago, IL). All statistical tests were two-tailed, and the significance level was set at $p < 0.05$.

Results

Sample description

The general characteristics of both male and female subjects are presented by country in Tables 1 and 2. A total of 5766 males (11.2 ± 3.3 years) and 6333 females (11.4 ± 3.3 years) were included in this study. In only 8 out of 13 countries, anthropometric data were obtained, and consequently the BMI of only 3934 males and 4498 females was calculated, and 64.5 % males and 67.8% females of these were classified as normal weight. Medium socioeconomic class was the most common SEL (44.0% males and 47.0% females).

China contributed the highest number of males to the total male study sample (Table 1) (n = 2705, 47% of total male study sample) and the lowest Turkey (n = 67, 1% of total male sample). The youngest females were from France (8.9 ± 3.4 years) and the oldest were from Iran (13.0 ± 4.1 years). China provided the highest number of females (Table 2) (n = 2922) and Uruguay the lowest (n = 71). The youngest females were from Mexico (9.4 ± 3.7 years) and the oldest were from Iran (13.0 ± 3.0 years).

Total fluid intake

Daily TFI was obtained in 3611 children (4–9 years, 51.75 % females) and 8109 adolescents (10–17 years, 53.11 % females) (Table 3). The highest fluid intake was observed in Uruguayan males (2.13 ± 0.80 and 2.46 ± 1.04 L/day, for 4–9 years and 10–18 years, respec-tively) and females (2.47 ± 0.92 and 2.61 ± 1.16 L/day, for 4–9 years and 10–18 years, respectively). In contrast, the lowest fluid intake in children and adolescents was observed in Belgian males (0.90 ± 0.43 and 0.99 ± 0.44 L/day, for 4–9 and 10–18 years, respectively) and females (0.73 ± 0.39 and 0.91 ± 0.41 L/day, respectively).

Adherence to EFSA reference values

The non-adherence to EFSA AIs for fluids in children and adolescents is shown in Fig. 1. A high proportion of the participants do not meet the EFSA AIs for fluids. In children, the lowest non-adherence was observed in Uruguay, males (10 %) and females (<20 %), matching with the country which provided fewer participants, and the highest non-adherence was observed in Belgium, males and females (>90 %). No significant differences for adherence were observed between males and females in all countries.In adolescents, the lowest non-adherence to EFSA AIs for fluids was observed in Uruguay (males and females <25 and 15 %, respectively) and the highest non-adherence was observed in Belgium (males and females >90 %). Non-adherence to EFSA AIs for fluids was significantly higher in males than in females in Indonesia, Brazil, Argentina, Mexico and Poland.In Figs. 2 and 3, compliance with EFSA AIs for fluids (yes/no) is considered as the dependent variable and gender as the independent variable. The odds ratios (OR) represented the likelihood of not reaching the EFSA AIs for fluids when being female as compared to being male. In the total sample, females were more likely to meet the EFSA AIs for fluids than the males (4–9 years: 28 %, OR 0.72, p = 0.002; 10–18 years: 20 %, OR 0.80, p = 0.001). When analysing the samples of the countries individually, the probability of not meeting the EFSA AIs for fluids reached significance only in Spain and Poland, and moreover only in the age group 10–18 years: females were more likely to meet the EFSA AIs for fluids than males (Spain: 57%, OR 0.43, p = 0.041; and Poland: 62%, OR 0.38, p = 0.010).

In Figs. 4 and 5, compliance with EFSA recommendation for TFI (yes/no) is considered as dependent variable and age 4–9 as

Table 1. *General characteristics of the male study population, categorized by country*

	Sample size, n (% relative females)	Age, mean (SD)	Age categories, % (n)		BMI, mean (SD)	BMI classification[a], % (n)				Socio-economic level[c], % (n)		
			4–9 years	10–18 years		Underweight	Normal	Overweight	Obesity	AB	C	D
Mexico	406 (59)	9.0 (3.5)	58 (234)	42 (172)	n.a.	n.a.	n.a.	n.a.	n.a.	5 (21)	39 (157)	56 (228)
Brazil	395 (51)	10.3 (4.2)	46 (183)	54 (212)	n.a.	n.a.	n.a.	n.a.	n.a.	22 (87)	44 (172)	34 (136)
Uruguay	68 (49)	10.1 (3.7)	44 (30)	56 (38)	n.a.	n.a.	n.a.	n.a.	n.a.	31 (21)	28 (19)	41 (28)
Argentina	74 (38)	11.2 (4.5)	41 (30)	59 (44)	n.a.	n.a.	n.a.	n.a.	n.a.	27 (20)	32 (24)	41 (30)
Spain	106 (53)	10.5 (4.0)	41 (43)	59 (63)	19.4 (4.0)	9.4 (10)	59.4 (63)	25.5 (27)	5.7 (6)	25 (27)	42 (45)	32 (34)
France	211 (53)	8.9 (3.4)	56 (119)	44 (92)	17.6 (3.5)	18.0 (38)	63.8 (134)	15.2 (32)	2.9 (6)	n.a.	n.a.	n.a.
Belgium	375 (45)	10.3 (1.3)	31 (116)	69 (259)	18.4 (3.4)	6.3 (23)	69.6 (256)	17.7 (65)	6.5 (24)	n.a.	n.a.	n.a.
UK	157 (44)	10.0 (3.5)	43 (67)	57 (90)	21.2 (6.2)	8.6 (10)	41.7 (48)	27.0 (31)	22.6 (26)	16 (25)	46 (73)	38 (59)
Poland	170 (52)	10.1 (4.1)	47 (80)	53 (90)	18.1 (3.8)	3.7 (1)	77.8 (21)	14.8 (4)	3.7 (1)	8 (13)	65 (110)	28 (47)
Turkey	67 (18)	13.0 (4.1)	24 (16)	76 (51)	20.9 (3.9)	3.0 (2)	70.1 (47)	11.9 (8)	14.9 (10)	n.a.	n.a.	n.a.
Iran	367 (47)	12.8 (2.9)	23 (84)	77 (283)	20.8 (4.9)	9.3 (33)	56.9 (203)	21.6 (77)	12.3 (44)	32 (119)	29 (108)	38 (140)
China	2705 (48)	12.1 (2.6)	20 (540)	80 (2165)	19.1 (3.7)	11.1 (298)	65.8 (1766)	17.2 (461)	5.9 (159)	n.a.	n.a.	n.a.
Indonesia	443 (44)	10.2 (3.9)	45 (200)	55 (243)	n.a.	n.a.	n.a.	n.a.	n.a.	26 (117)	57 (252)	17 (74)
Total population[b]	5766 (48)	11.2 (3.3)	32 (1844)	68 (3922)	19.2 (4.0)	10.5 (415)	64.5 (2538)	17.9 (705)	7.0 (276)	21 (450)	44 (960)	35 (776)

Data are presented as percentage (n) or mean (95% CI)
n.a. not available, BMI body mass index
[a] BMI (kg/m2) classification according to IOTF guidelines [8, 9]
[b] Only countries with available data on the presented characteristics were included
[c] Category AB represents individuals with professional/managerial occupations, C represents individuals with other non-manual occupations and individuals having skilled manual occupations, and D represents individuals with semi-/unskilled manual occupations and people dependent on state benefits

Table 1. *General characteristics of the female study population, categorized by country*

	Sample size, n (% relative males)	Age, mean (SD)	Age categories, % (n)		BMI, mean (SD)	BMI classification[a], % (n)				Socio-economic level[c], % (n)		
			4–9 years	10–18 years		Underweight	Normal	Overweight	Obesity	AB	C	D
Mexico	287 (41)	9.4 (3.7)	53 (153)	47 (134)	n.a.	n.a.	n.a.	n.a.	n.a.	3 (8)	41 (119)	56 (160)
Brazil	384 (49)	10.3 (4.2)	43 (166)	57 (218)	n.a.	n.a.	n.a.	n.a.	n.a.	20 (75)	47 (181)	33 (128)
Uruguay	71 (51)	10.9 (4.0)	42 (30)	58 (41)	n.a.	n.a.	n.a.	n.a.	n.a.	27 (19)	25 (18)	48 (34)
Argentina	119 (62)	10.1 (4.2)	50 (59)	50 (60)	n.a.	n.a.	n.a.	n.a.	n.a.	25 (30)	39 (46)	36 (43)
Spain	95 (47)	10.1 (4.0)	44 (42)	56 (53)	19.3 (3.8)	4.3 (4)	63.2 (60)	18.9 (18)	13.7 (13)	19 (18)	45 (43)	36 (34)
France	188 (47)	9.6 (3.4)	46 (87)	54 (101)	17.4 (3.6)	14 (26)	71.5 (133)	9.1 (17)	5.4 (10)	n.a.	n.a.	n.a.
Belgium	465 (55)	10.3 (1.2)	32 (150)	68 (315)	18.3 (3.4)	8.4 (38)	66.5 (302)	19.6 (89)	5.5 (25)	n.a.	n.a.	n.a.
UK	201 (56)	10.4 (3.6)	40 (81)	60 (120)	20.1 (6.1)	18.5 (26)	53.2 (75)	14.9 (21)	13.5 (19)	15 (31)	48 (97)	36 (73)
Poland	160 (48)	9.8 (3.4)	46 (74)	54 (86)	17.8 (3.6)	9.1 (1)	72.7 (8)	18.2 (2)	n.a.	8 (12)	59 (94)	34 (54)
Turkey	309 (82)	9.6 (3.6)	48 (148)	52 (161)	18.7 (4.4)	16.5 (51)	53.4 (165)	14.9 (46)	15.2 (47)	n.a.	n.a.	n.a.
Iran	417 (53)	13.0 (3.0)	22 (93)	78 (324)	21.1 (4.6)	6.8 (28)	61.6 (253)	22.6 (93)	9.0 (37)	29 (121)	36 (152)	35 (144)
China	2922 (52)	12.3 (2.7)	20 (580)	80 (2342)	18.3 (3.2)	17.7 (509)	71.1 (2055)	9.2 (265)	2.1 (62)	n.a.	n.a.	n.a.
Indonesia	558 (56)	10.9 (4.1)	37 (206)	63 (352)	n.a.	n.a.	n.a.	n.a.	n.a.	27 (153)	60 (336)	12 (69)
Total population[b]	6333 (52)	11.4 (3.3)	30 (1930)	70 (4403)	18.9 (3.8)	15.1 (683)	67.8 (3051)	12.2 (551)	4.7 (213)	20 (467)	47 (1086)	32 (739)

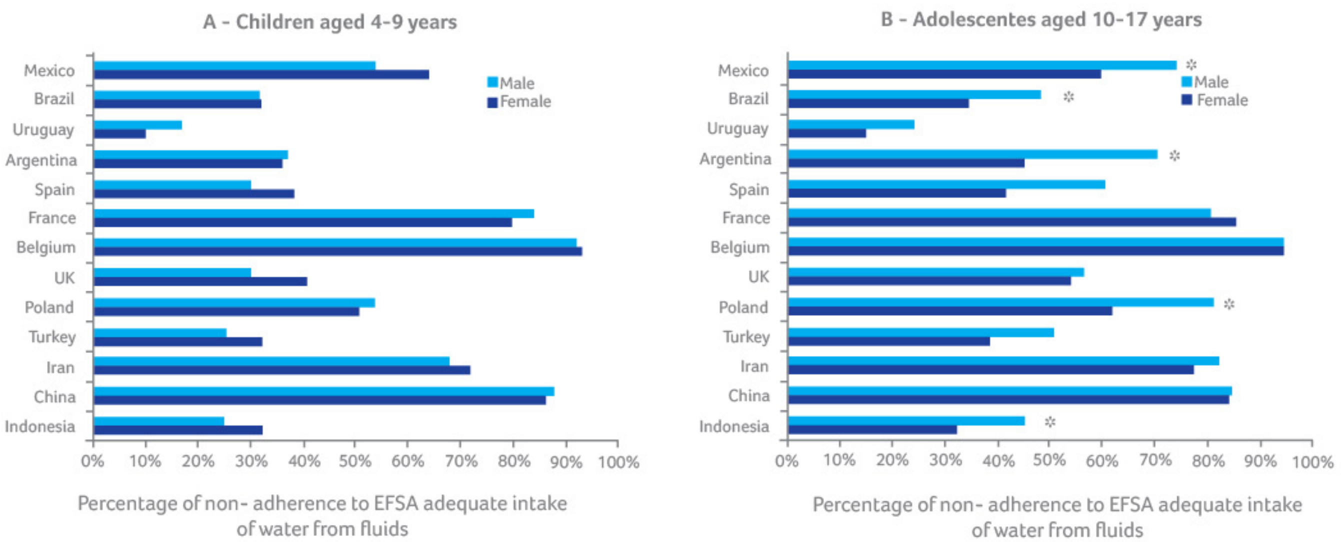
Data are presented as percentage (n) or mean (95 % CI)
n.a. not available, BMI body mass index
[a] BMI (kg/m2) classification according to IOTF guidelines [8, 9]
[b] Only countries with available data on the presented characteristics were included
[c] Category AB represents individuals with professional/managerial occupations, C represents individuals with other non-manual occupations and individuals having skilled manual occupations, and D represents individuals with semi-/unskilled manual occupations and people dependent on state benefits

independent variable. The odds ratio (OR) represents the percentage not reaching the EFSA recommendation for TFI when being older than 9 years.

Differences were found between country and gender (males Fig. 4; females Fig. 5). The probability of non-compliance with EFSA AI for fluids increased significantly when being older than 9 years in Spain (OR 3.345, $p = 0.021$ in males), UK (OR 2.689, $p = 0.019$, in males), Poland (OR 4.871, $p < 0.001$ in males), Iran (OR 3.747, $p < 0.001$ in males and OR 2.702, $p = 0.003$ in females) and the total sample (OR 1.645, $p < 0.001$ in males and OR 1.625, $p < 0.001$ in females). In the rest of the countries except for China, children older than 9 years were more likely to comply with the EFSA AIs; however, this was not significant. In China, the probability of not compliance with EFSA recommendation was lower when being older than 9 years in both genders, although this did not reach significance.

	Total						Males						Females					
	n	Mean	SD	Median	25th	75th	n	Mean	SD	Median	25th	75th	n	Mean	SD	Median	25th	75th
Children (4–9 years)																		
Mexico	387	1.35	0.65	1.23	0.88	1.64	234	1.39	0.65	1.27	0.89	1.71	153	1.28	0.64	1.16	0.84	1.51
Brazil	349	1.67	0.63	1.55	1.20	2.03	183	1.68	0.61	1.55	1.23	2.10	166	1.66	0.66	1.55	1.20	1.94
Uruguay	60	2.24	0.86	2.05	1.70	2.72	30	2.13	0.80	2.00	1.53	2.72	30	2.35	0.92	2.16	1.86	2.78
Argentina	89	1.78	0.92	1.54	1.17	2.03	30	1.64	0.63	1.58	1.23	1.99	59	1.86	1.03	1.50	1.14	2.20
Spain	85	1.64	0.67	1.50	1.13	1.97	43	1.78	0.77	1.68	1.18	2.08	42	1.50	0.53	1.43	1.09	1.73
France	206	1.02	0.35	0.92	0.77	1.22	119	1.02	0.35	0.95	0.77	1.23	87	1.01	0.36	0.88	0.77	1.21
Belgium	266	0.84	0.41	0.81	0.54	1.08	116	0.90	0.43	0.90	0.60	1.16	150	0.79	0.39	0.75	0.49	1.03
UK	148	1.56	0.57	1.51	1.18	1.87	67	1.69	0.64	1.65	1.24	2.08	81	1.45	0.49	1.46	1.13	1.71
Poland	154	1.39	0.44	1.29	1.07	1.64	80	1.42	0.50	1.28	1.06	1.69	74	1.37	0.38	1.29	1.09	1.64
Turkey	164	1.74	0.72	1.67	1.23	2.12	16	1.81	0.75	1.84	1.06	2.31	148	1.73	0.71	1.60	1.23	2.04
Iran	177	1.24	0.42	1.19	0.95	1.46	84	1.32	0.44	1.25	1.02	1.47	93	1.16	0.39	1.13	0.87	1.41
China	1120	0.97	0.43	0.89	0.64	1.19	540	0.98	0.42	0.90	0.65	1.20	580	0.95	0.43	0.86	0.63	1.17
Indonesia	406	1.88	0.77	1.73	1.26	2.44	200	1.94	0.78	1.82	1.36	2.55	206	1.83	0.77	1.68	1.19	2.29
Total	3611	1.32	0.68	1.18	0.84	1.64	1742	1.34	0.67	1.20	0.86	1.67	1869	1.30	0.69	1.16	0.81	1.62
Adolescents (10–18 years)																		
Mexico	306	1.51	0.85	1.31	0.91	1.91	172	1.46	0.74	1.33	0.96	1.81	134	1.57	0.97	1.29	0.84	2.05
Brazil	430	2.01	0.90	1.80	1.40	2.54	212	2.03	0.92	1.89	1.35	2.55	218	1.99	0.88	1.75	1.40	2.48
Uruguay	79	2.54	1.04	2.23	1.75	3.16	38	2.46	0.92	2.21	1.77	3.04	41	2.61	1.16	2.25	1.75	3.42
Argentina	104	1.77	0.81	1.59	1.21	2.11	44	1.83	0.97	1.57	1.17	2.24	60	1.72	0.68	1.63	1.26	2.07
Spain	116	1.78	0.70	1.62	1.33	2.14	63	1.80	0.64	1.63	1.36	2.15	53	1.75	0.76	1.57	1.27	2.15
France	193	1.25	0.45	1.16	0.93	1.47	92	1.35	0.46	1.28	1.04	1.57	101	1.17	0.43	1.07	0.91	1.32
Belgium	574	0.95	0.43	0.91	0.69	1.14	259	0.99	0.44	0.95	0.71	1.18	315	0.91	0.41	0.86	0.65	1.09
UK	210	1.67	0.73	1.55	1.15	2.09	90	1.77	0.75	1.61	1.23	2.16	120	1.60	0.72	1.45	1.10	1.96
Poland	176	1.48	0.48	1.41	1.12	1.73	90	1.44	0.46	1.42	1.10	1.69	86	1.51	0.51	1.39	1.14	1.93
Turkey	212	1.91	0.80	1.77	1.26	2.46	51	1.98	0.86	1.91	1.16	2.77	161	1.88	0.78	1.72	1.31	2.34
Iran	607	1.32	0.51	1.26	0.94	1.58	283	1.42	0.53	1.36	1.00	1.70	324	1.23	0.47	1.16	0.86	1.52
China	4507	1.15	0.54	1.05	0.76	1.43	2165	1.24	0.57	1.13	0.81	1.53	2342	1.08	0.49	0.99	0.72	1.33
Indonesia	595	2.03	0.83	1.91	1.37	2.66	243	2.05	0.86	1.97	1.34	2.75	352	2.01	0.81	1.90	1.38	2.62
Total	8109	1.35	0.71	1.19	0.84	1.65	3802	1.40	0.71	1.25	0.90	1.73	4307	1.30	0.70	1.13	0.80	1.59

Fig. 1. *Non-adherence to EFSA adequate intake for fluids (equals 80 % of EFSA adequate intake for total water intake) by age group. *p value of the Pearson Chi-square test < 0.05 (differences between sexes within countries)*



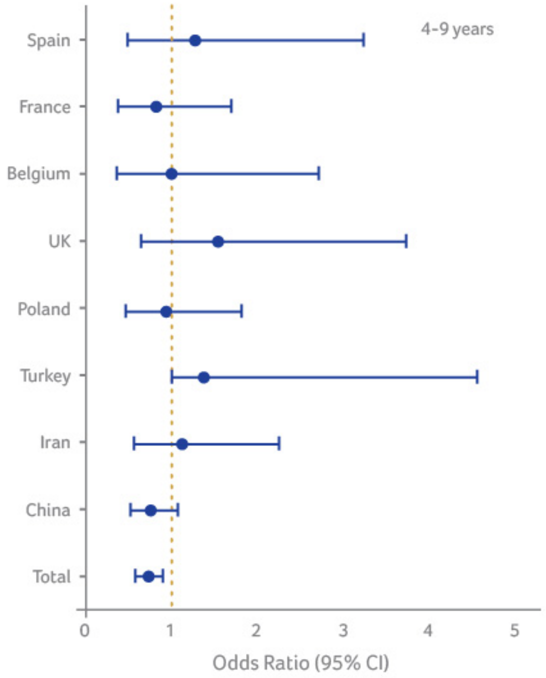


Fig. 2. *Association (odds ratio, 95 % CI) between compliance with EFSA adequate intake for fluids (equals 80 % of EFSA adequate intake for total water intake) and gender, per country in children aged 4–9 years. The logistic regression model was adjusted for age, BMI and SEL, and males were considered as reference. *p value < 0.05*

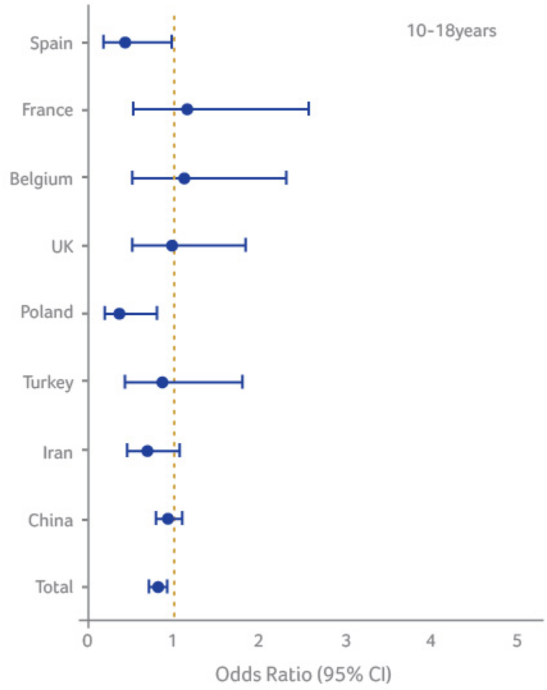


Fig. 3. *Association (odds ratio, 95 % CI) between compliance with EFSA adequate intake for fluids (equals 80 % of EFSA adequate intake for total water intake) and gender, per country in adolescents aged 10–17 years. The logistic regression model was adjusted for age, BMI and SEL, and males were considered as reference*

Discussion

The results of this compilation of cross-sectional studies provide important information about the fluid intake of children in 13 countries, and such a global perspective has not previously been reported. According to the EFSA reference values for total water intake for these age categories, more than fifty percent of the whole study population are at risk of an inadequate intake.

Large differences between countries and age groups were found. Belgium had the highest percentage (>90 %) of non-adherence to the EFSA AIs for fluids in both children and adolescents, followed by China, France (both >80 %) and Iran (70 %). In Belgium, China and Iran, the completion of the fluid diary was done by the teachers in the school and by the parents at home, whereas in the rest of the countries, the diary was filled by main caretaker (mums). This fact may explain the lower intakes recorded in the firsts countries. Maybe the intake in these other countries was overestimated because of social desirability and is the intake of Belgium actually more accurately reflecting the true intake. In France, a study [6] with a representative sample of children and adolescents suggested that fluid intake was low (1–1.1 L/day), very similar to the values obtained in the present study. Moreover, another study demonstrated that based on osmolality urine levels, two-thirds of French children had a hydration deficit in the morning when they went to school, despite having breakfast [7]. Both these studies support our findings of an inadequate fluid intake in French children. In Europe, data from the HELENA study [15] performed in adolescents, and the German DONALD study [26] performed in both children and adolescents, suggested higher values of fluid intakes than our study did. However, the tool used in the HELENA study was not specifically developed to measure fluid intake [15]. In addition, the software used in the HELENA study to collect the 24-h recalls (HELENA-DIAT [11]) was designed to remind the adolescents to fulfil the questionnaire to state the amount of water intake as is an issue susceptible to oversight such as other add-ons like butter, or salad dressing.

Uruguay (<20 %) and Brazil (<40 %) had the lowest percentages of non-adherents to EFSA AIs for fluids. Together with Argentina, Turkey and Indonesia, Uruguay had the highest mean fluid intakes, similar to the values observed in a previous study in Brazil [18]. One of the plausible explanations for this finding could be the high humidity and temperatures in these countries, which result in people drinking more [30]. This raises one of the limitations of present analysis of cross-sectional surveys. The fact that the surveys were performed in the same period of the year, and therefore the impact of the seasons on TFI was neglected. Nevertheless, the data collection was performed during the spring or autumn, periods expected to have a mild climate. The impact of climate on TFI should be investigated by recording the temperature and humidity in future surveys and considered in analyses.

One remarkable point throughout this analysis is that there were no large differences in fluid consumption between the genders. Generally males drank more fluids than females in all the countries included in this survey (except females from Uruguay and Argentina aged 4–10 years, and females from Mexico and Uruguay aged 10–18 years). However, females were more likely to comply with EFSA AIs for fluids. Gender differences were more noticeable in the adolescents throughout the countries and in the total sample, probably because at these ages, females become more health conscious and may drink more [23].

The results also indicated that compliance with EFSA AIs for fluids is greater among children 4–9 years old than among children 10–18 years old in almost all included countries. A plausible explanation could be that with transition to adolescence children gain more independence with respect to food/fluid consumption. While they still consume the majority of meals and snacks at home, but they also start taking decisions regarding food choices away from home [22]. With

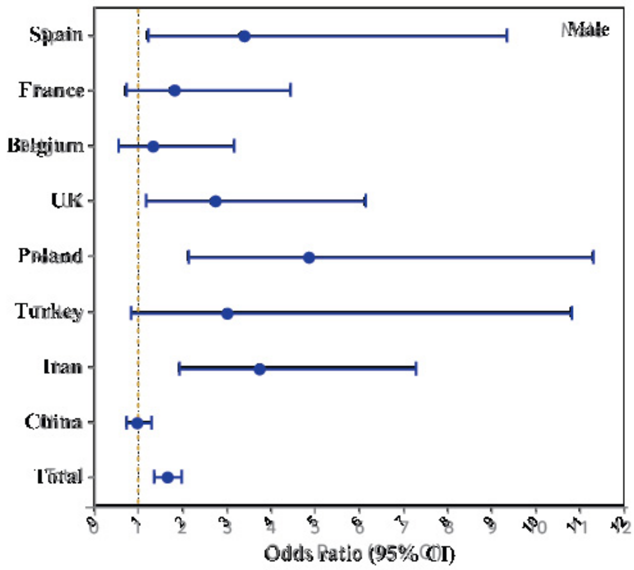


Fig. 4. *Association (odds ratio, 95 % CI) between compliance with EFSA adequate intake for fluids (equals 80 % of EFSA adequate intake for total water intake) and age group per country in males. The logistic regression model was adjusted for BMI and SEL, and children aged 4–9 were considered as reference.*

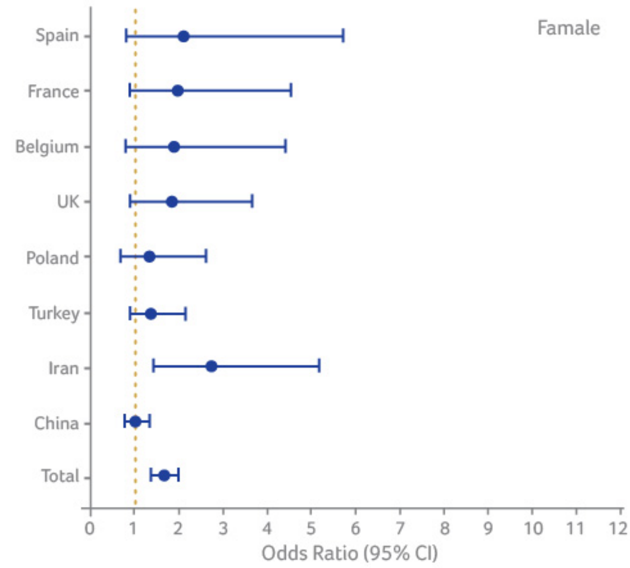


Fig. 5. *Association (odds ratio, 95 % CI) between compliance with EFSA adequate intake for fluids (equals 80 % of EFSA adequate intake for total water intake) and age group per country in females. The logistic regression model was adjusted for BMI and SEL, and children aged 4–9 were considered as reference.*

the transition to adolescence, a possible transition in the preference for certain beverage types might be anticipated. This topic was, however, outside the scope of the current paper, but will be addressed in a separate paper [20].

Several limitations should be considered when interpreting the data presented. Firstly, the lack of representativeness of the samples in terms of "n", age groups and gender within the countries suggests that these data should be interpreted cautiously: as country-, age- and gender-specific data points. Secondly, the lacks of data regarding BMI or SEL in some of the countries did not allow having a complete set up of the situation. Another limitation to consider is related to the method used for recording fluid intake: for children younger than 12 years, the primary caretaker was responsible to record the fluid intake of the child. It should be considered that a parent might find it difficult to accurately estimate fluid intake consumed at school. Therefore, fluid intake of the children/adolescent could be over- or under-reported. However, fluid intake of all participants was recorded over a period of 7 days including the weekend during which the children are at home and the caregiver can observe and record the intake of their child more carefully. Future research should focus on demonstrating the health impact of a certain level of fluid intake, in order to progress towards a reference value based on scientific evidence and not only on observed intakes. Regardless of which cut-off was used to evaluate the wide of the problem (meet/not meet water intake recommendations), the observation from these cross-sectional surveys remains the same: that a high number of children and adolescents worldwide have a low TFI. For example, when using the dietary reference values set in China (which use those established by the Institute of Medicine-IOM-in USA [2]), 86% of both males and females were at risk of an inadequate water intake, which is a very similar percentage to the ones we have obtained based on the EFSA recommendations even when the values established by the IOM are higher than the ones from EFSA. This is because there are almost no subjects located between the EFSA reference values and IOM ones, regarding drinking fluids.

The strengths of all 13 cross-sectional surveys include the use of a standardized 7-day fluid-specific record, considered the reference method to assess fluid intake and the amount of water volumes also in young population groups [31, 32]. This fluid-specific record was also supported by visual aids, to facilitate the recording of consumed volumes. Moreover, the two methods used for the recruitment (the quota-based sample -the best method to evaluate intakes [19]- and stratified clusterization) used to approach the survey in 10 and in the other three countries, respectively, are recognized as valuable methods to provide enough sample by age of participants, regions of the country and different socioeconomic groups for meaningful analysis.

Conclusions

The most important conclusions from this analysis are that a high proportion of children and adolescents are at risk of an inadequate fluid intake and that the probability for non-adherence to EFSA AIs for fluids is higher among males than among females, and among those aged from 4 to 9 than among those aged from 10 to 18. Uruguay followed by Brazil and Belgium followed by China were those countries with the highest proportion of adherents and non-adherents, respectively, to EFSA AIs for fluids. As a number of studies have demonstrated that having a low fluid or water intake can compromise several body functions, this conclusion justifies encouraging these populations to increase their plain water intake. Future studies should focus on the observation of longitudinal changes to determine whether the maintained restrictive water intake can result in longterm health impacts from the early stages of life.

Acknowledgments

Data collection was performed by the Center of Disease Control in China; the National Nutrition and Food Technology Research Institute in Iran; the School of Public Health, Université Libre de Bruxelles and the Club Européen des Diététiciens de l'Enfance in Belgium. We acknowledge Christine Jean, Market Research & Consumer Intelligence Danone Waters and the entire MRCI Team to raise the methodology of fluid intake surveys to the current standard and to guide IPSOS in Mexico, UK and Turkey; TNS in Argentina, France, Germany, Poland and Spain; Nielsen in Indonesia; and GFK in Brazil and Uruguay, with the

preparation of the survey.

Conflict of interest
IG is an employee of Danone Research. JS-S, JS, LAM, SK, JG, HM are members of advisory board on fluid intake of Danone Research. AM and NE are employer at NNFTRI, an institute which has received a research grant from Damavand mineral water company (a brand of Danone Group in Iran).

Ethical Standard
The protocol of the unpublished surveys was reviewed and approved by the Institutional Review Board, Office of Research Compliance of the University of Arkansas (IRB Protocol # 14-12-376). The Belgian survey was approved by the ethical committee of the Queen Fabiola Children's University Hospital of Brussels approved (on 20 September 2011) (reference: CEH-N°58/11). The Chinese surveys were approved by the Ethical Review Committee of the National Institute for Nutrition and Food Safety, Chinese Center for Disease Control and Prevention. Informed consent was obtained by all participating children or adolescents and their parents, as appropriate. All data were recorded anonymously.

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INTAKE OF WATER AND BEVERAGES OF CHILDREN AND ADOLESCENTS IN 13 COUNTRIES

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Abstract

Purpose

To describe the intake of water and all other beverages in children and adolescents in 13 countries of three continents.

Methods

Data of 3611 children (4–9 years) and 8109 adolescents (10–17 years) were retrieved from 13 cross-sectional surveys (47% males). In three countries, stratified cluster sampling design was applied to randomly recruit schools classes. A quota method was applied in the other countries to randomly recruit participants. Details on the intake of all fluid types were obtained with a fluid-specific record over 7 consecutive days.

Results

In the total sample, the highest mean intakes were observed for water (738 ± 567 mL/day), followed by milk (212 ± 209 mL/day), regular soft beverages (RSB) (168 ± 290 mL/day) and juices (128 ± 228 mL/day). Patterns characterized by a high contribution of water, RSB or hot beverages to total fluid intake were identified among the countries with close geographical location. Adolescents had a significantly lower milk intake and higher intake of RSB and hot beverages than children in most countries. The most consistent gender difference observed was that in both age groups males reported a significantly higher RSB consumption than females.

Conclusion

On average, water was the fluid consumed in the largest volume by children and adolescents, but the intake of the different fluid types varied substantially between countries. Since the RSB intake was as large, or even larger, than water intake in some countries, undertaking actions to improve fluid intake habits of children and adolescents are warranted.

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Introduction

The World Health Organization (WHO) has raised concern regarding an excessive intake of sugar-sweetened beverages (SSB) for children [1]. This concern is based on a meta-analysis of long-term prospective cohort studies concluding that children consuming the largest intakes of SSB had greater likelihood of being overweight or obese than children with the lowest intakes [2]. Moreover, the sugars present in SSB have been associated with dental carries prevalence both in children and adults [2, 3]. Consequently, the WHO has set recommendations for intake of free sugars to <10% of total energy intake and suggests a further reduction to <5% of total energy intake [1]. Evidence has suggested that a reduction in energy intake facilitating weight management can be achieved among regular SSB consumers if they replace their SSB with drinking water [4, 5].

Now that this recommendation has been made, surveying populations is globally needed to assess the intake patterns of different fluid types (water and all other beverages). Several large cohort or cross-sectional studies have already reported the intake of different fluid types in children [6–9]. In 2014, Özen et al. [10] published a systematic review of studies assessing beverage consumption across age groups. In children, plain water contributed up to 58 % of total beverage intake, with great variability from 21 to 58% between countries [10]. This number was increased to 51–75% in adolescents. Surprisingly, even though the studies included in this review assessed beverage consumption, they did not all report the intake of water [10]. Furthermore, other inconsistencies were noted in the study design, dietary assessment methods, classification of beverages and age categories which limit the comparison of results between countries. To make an inter-country comparison, a review containing surveys which assessed fluid intake with the same methodology and reported intake of all fluids would be needed. Ideally, the sample of such surveys would be representative of the national sample and would cover the same and wide age range. The review by Özen et al. [10] showed also that for one country, such as the USA, several studies reporting on fluid intake of children are available. However, fluid intake of children and adolescents remains to be assessed in numerous countries worldwide. The aim of the present pooled analysis was therefore to describe the intake pattern of water and all other beverages in children and adolescents, aged 4 up to 17 years in 13 countries of three continents. Differences in intakes between sex and age groups are also reported.

Methods

Design and study population

This pooled reanalysis was performed on the individual data of participants aged 4–17.9 years of 13 cross-sectional surveys. The primary objective of all surveys was to assess the intake of drinking water and different types of beverages. The secondary objective was to assess the barriers or believes individuals have about the consumption of water or other fluid types. The surveys included in the pooled reanalysis were conducted in Latin America (Mexico, Brazil, Argentina, Uruguay), Europe (Spain, France, Belgium, UK, Poland, Turkey) and Asia (Iran, China, Indonesia) between 2008 and 2014, either by private research organizations, or by the Université libre de Bruxelles/the Club Européen des Diététiciens de l'Enfance (CEDE), by the Iranian National Nutrition and Food Technology Research Institute (NNFTRI) or by the Chinese Center for Disease Control (CDC). All surveys were initiated by or in collaboration with Danone Research. The individual surveys called Liq.In7 (abbreviation of Liquid Intake over 7 days) took place between 2008 and 2014.

This pooled reanalysis contained both original and published fluid intake data. The protocol of the published surveys has been described in detail elsewhere [11–15]. Annex 1 summarizes the sampling method, the exclusion criteria, the period of data collection, the age range of recruited participants and the dietary assessment method of the retrieved cross-sectional surveys performed among children, adolescents and adults. Data of adults are reported elsewhere [16, 17]. Data collection was organized during a period of the year with an expected mild climate (spring or fall) in order to minimize the effect of temperature as much as possible. In brief, the surveys performed in Belgium, Iran and China used a comparable recruitment method: entire school classes were recruited via a random, stratified cluster sampling. The school classes were stratified for school grade or age of participants, regions of the country and the type of educational system. The survey in Belgium therefore focussed on the age range of 8–13 years and in Iran and China 8–17 years. Parents of the recruited school children received information on the study via parent meetings, written information sheet or phone calls. Surveys conducted in the 10 other countries randomly recruited participants with a quota-based method. Quotas were set for age, gender, region of the country, habitat and/or socioeconomic characteristics. Parents were contacted via a database of individuals volunteering to population surveys or via a systematic door-to-door approach with an invitation for their child to participate.

All parents and children willing to participate in the sur-vey received detailed information about the survey objectives, what was expected from them, as well as a disclosure of the survey's provisions to preserve confidentiality, risks and benefits, and a clear explanation about their option to participate voluntarily or not in the survey. After offering a detailed description of the survey, parents were asked for their oral approval to let their child participate. No monetary incentive was offered for taking part in the survey. All data were recorded in an anonymous way. Therefore, participants cannot be identified, directly or through identifiers linked to the participants. The survey protocol of the unpublished surveys was reviewed and approved by the University of Arkansas Review Board (ref. 14-12-376).

Assessment of fluid intake

A fluid-specific record was provided to participants of all surveys in order to collect information on all their fluid consumption over 7 consecutive days. These 7-day fluid records and the associated written information were presented to the participants in the official language of the country in a paper format, except for participants in France who filled in their fluid record online. An investigator delivered and explained the fluid record to the participants during a face-to-face interview at home. For children younger than 12 years, the primary care giver of the child was requested to complete the fluid record. After 7 days, a second home visit of the investigator took place to collect the fluid record and to ensure a complete record. Surveys performed in Belgium, Iran and China deviated from this protocol as they recruited school classes [13, 14]. In these cases, both parents and teachers were involved in the completion of the fluid record. All questionnaires were verified by the researchers upon completion, and incomplete answers were clarified at the next visit.

The 7-day fluid records in all surveys were structured in order to capture the same type of information on the fluids consumed. Besides an introduction with instruction on the completion of the record, the 7-day fluid record consisted of blank tables, one for each day. Participants were instructed to complete a line in the table every time they drank anything, at any time of the day both inside their home and outside. To remind them of consumptions throughout the day, the following moments were indicated in the table: before breakfast, during breakfast, at midmorning (between breakfast and lunch), during lunch, between lunch and afternoon tea, during afternoon tea, in the afternoon (between afternoon tea and dinner), during dinner, after dinner/before going to sleep and late at night/at dawn. For each consumption, the following questions had to be registered in the table:

- **(a)** Fluid type: What did you drink in or outside of your home? A list of fluids types that corresponded to the one presented in annex 2 was provided.
- **(b)** Brand: What brand/flavour/packaging type did you consume? A list of fluids and brands was provided.
- **(c)** Container: From which container did you drink? A photographic booklet of standard containers of fluids was provided, and in China also an additional scaled water container.
- **(d)** Quantity: How much did you drink? A code that corresponded to the number of whole units and/or fractions of the container had to be registered.
- **(e)** Form of Consumption: How did you consume the fluid? E.g. Alone or did you mix with other products (e.g. concentrated juice syrup, energy drinks)? With which ones? Was the fluid hot or cold (with or without ice cubes)? Participants could also indicate whether or not

they added sugar to their fluid.

(f) Company: With whom did you consume the drink? A list of options was presented

(g) Activity: What were you doing while you were drinking? A list of possible activities was provided.

(h) Location: Where did you drink? A list of possible locations was provided.

(i) Reasons for consumption: For what reasons did you drink that fluid at that time? From a list of options participants could record maximum three reasons.

Classification of fluid types

The fluids recorded in all surveys were classified into: water (tap and bottled water), milk and milk derivatives, hot beverages (coffee, tea and other hot beverages), juices, regular soft beverages (RSB) (sugared and artificially sweetened, carbonated and non-carbonated soft drinks, energy drinks, sports drinks, other sugared or artificially sweetened soft drinks), alcoholic drinks and other beverages. A more detailed classification can be found in annex 2 of this paper. In five out of the 13 countries, the intake of artificially sweetened/diet beverages was separated from RSB. Since the mean intake of this fluid type was on average 7 mL/day, these fluids were included in the class of RSB to create homogeneity in the classification. In Argentina, Iran and Indonesia, only non-alcoholic beverages were recorded. In Belgium, coffee and tea intake was not recorded. However, soup intake was recorded and was classified into other beverages. In Spain and France, no fluids were classified into the group "other beverages". Additions (e.g. sugar or honey) by hand by the participant to a fluid were not taken into account while classifying a fluid. Total fluid intake (TFI) was defined as the sum of all categories previously described. For the each category, the age-, sex- and country-specific means of the absolute intakes over the 7 days were calculated.

Anthropometric data

Height in metres (m) and weight in kilograms (kg) were measured by the investigator in the surveys of Belgium, Poland, Iran and China and self-reported in the other surveys. No anthropometric data were collected in Mexico, Brazil, Uruguay, Argentina and Indonesia. When weight and height measures were available, body mass index (BMI) was calculated (in kg/m^2) and reported with the intention solely to describe the study samples. The proportion of male and female participants with underweight, normal weight, overweight and obesity as well as the socioeconomic status of the participants has been described elsewhere [11–15].

Statistical analysis

The same data cleaning was applied to the individual data of all 13 surveys. Participants who did not complete the full 7-day fluid intake record or who reported the exactly same intakes on ≥2 days over the 7 day period were excluded from the analysis, as well participants reporting a mean total daily fluid intake below 0.4 L/day or higher than 4 L/day as they are considered to be non-plausible intakes. The final sample size for this analysis was 11,720 participants, who were classified into children (4–9.9 years) and adolescents (10–17.9 years).

Continuous and categorical data are presented as mean (SD) and percentage (n), respectively. In annex 3 of this paper, standard error of the mean (SEM), median and additional percentiles (5^{th}, 10^{th}, 25^{th}, 75^{th}, 90^{th}, 95^{th}) of the 7-day intakes of fluids are also reported. The effect of age and sex on the intake of the different beverages types was tested with a student's test. Analyses were performed using the JMP software version 10.0.0 (SAS Institute Inc., Cary, NC). All statistical tests were two-tailed, and the significance level was set at $p < 0.01$ to correct for the multiple testing.

Results

Table 1 describes the sample size, age and BMI of both age groups by country. The proportion of children and adolescents in the sample of each country was balanced, except for Belgium, Iran and China. In the latter three samples, 68–80% of the participants were adolescents. Consequently, the mean age of the children in these three samples was higher than the mean age of the children in the other samples.

In general, across the total samples of the countries, the highest daily intakes were observed for water (738 ± 567 mL/day), followed by milk (212 ± 209 mL/day), RSB (168 ± 290 mL/day) and juices (128 ± 228 mL/day). There was a large intercountry variation in the intake of a given fluid type. Daily water intake ranged from 296 mL/day in Poland to 1516 mL/day in Indonesia, whereas daily milk intake ranged from 123 mL/day in Indonesia to 530 mL/day in Uruguay. The intake of RSB and juices ranged from 64 mL/day in China to 625 mL/day in Argentina and from 21 mL/day in Indonesia to 555 mL/day in Brazil, respectively. The age-, sex- and country-specific means of intake of the different fluid types are presented in Tables 2 and 3.

Despite these large differences in volumes of intake of the different fluid types, some samples had comparable patterns of contribution of fluid types to TFI in the children (Fig. 1). The intakes of the Chinese and Indonesian sample were characterized by the largest contribution of water to TFI (respectively, 67 and 73% in total children sample) of all samples. In the samples of Spain, France, Belgium, Iran and Turkey, half of the TFI came from water (42–53% in total children sample). In these five samples, the other fluids contributed for a similar amount to TFI, except for the hot beverages. In the total children sample of Iran and Turkey, hot beverages contributed, respectively, for 10 and 13% to TFI, whereas in the French and Spanish sample they contributed only for 0–3%. Large contributions of hot beverages to TFI were also reported in the total children sample of Poland (34%) and Argentina (13%). Besides the large contribution of hot beverages, these two samples were also characterized by a contribution of RSB to TFI (22–35%) that was larger than the contribution of water to TFI (19–21%). Similar results were observed in the total children sample of Brazil, Mexico and UK: in Brazil the contribution of juices to TFI (29%) and in Mexico and UK the contribution of RSB to TFI (respectively 29–32%) were as large as the contribution of water to TFI (29–36%).

Similar patterns in the contribution of the different fluid types to TFI were identified among adolescents (Fig. 2). However, a comparison between the intake of children and adolescents indicated significant age effects (all with p value <0.001). The most consistently observed age effect was regarding the contribution of milk to TFI: adolescents in all samples except in Belgium and Mexico had a significantly lower milk intake than children. Moreover, adolescents had a significantly higher contribution of RSB to TFI than children in Brazil, Uruguay, Spain, Turkey and Iran. In the sample of Iran, children had a higher contribution of juices to TFI than adolescents, whereas in the Chinese sample the opposite was observed. The contribution of hot beverages to TFI was significantly higher among adolescent than among children in the sample of Brazil, Uruguay, Argentina, France Iran and China. The contribution of

Table 1. *General characteristics of the children and adolescent samples, categorized by country and gender*

Country	Sex	Children			Adolescents		
		Sample size n (%)	Age Mean (SD)	BMI Mean (SD)	Sample size n (%)	Age Mean (SD)	BMI Mean (SD)
Mexico	Male	234 (60)	6.52 (1.7)	ND	172 (56)	12.35 (2.3)	ND
	Female	153 (40)	6.58 (1.8)	ND	134 (44)	12.62 (2.3)	ND
Brazil	Male	183 (52)	6.30 (1.6)	ND	212 (49)	13.75 (2.3)	ND
	Female	166 (48)	6.18 (1.6)	ND	218 (51)	13.51 (2.4)	ND
Uruguay	Male	30 (50)	6.50 (1.7)	ND	38 (48)	12.87 (1.9)	ND
	Female	30 (50)	6.70 (1.5)	ND	41 (52)	13.93 (2.1)	ND
Argentina	Male	30 (34)	6.27 (1.6)	ND	44 (42)	14.57(2.0)	ND
	Female	59 (66)	6.47 (1.7)	ND	60 (58)	13.57 (2.6)	ND
Spain	Male	43 (51)	6.33 (1.5)	16.60 (2.8)	63 (54)	13.38 (2.3)	21.30 (3.4)
	Female	42 (49)	6.12 (1.7)	17.28 (2.9)	53 (46)	13.19 (2.1)	20.82 (3.7)
France	Male	119 (58)	6.34 (1.7)	15.74 (2.4)	92 (48)	12.24 (1.6)	19.92 (3.2)
	Female	87 (42)	6.48 (1.8)	16.07 (2.9)	101 (52)	12.27 (1.6)	18.54 (3.6)
Belgium	Male	116 (44)	8.82 (0.4)	17.37 (2.5)	259 (45)	11.02 (0.9)	18.91 (3.6)
	Female	150 (56)	8.88 (0.3)	17.14 (2.7)	315 (55)	10.96 (0.9)	18.90 (3.5)
UK	Male	67 (45)	6.61 (1.6)	21.58 (3.7)	90 (43)	12.51 (2.0)	21.58 (6.3)
	Female	81 (55)	6.70 (1.5)	20.80 (8.6)	120 (57)	12.89 (82.0)	19.69 (3.9)
Poland	Male	80 (52)	6.33 (1.6)	16.72 (3.1)	90 (51)	13.36 (2.5)	19.81 (3.7)
	Female	74 (48)	6.70 (1.5)	16.70 (3.4)	86 (49)	12.47 (2.1)	18.70 (3.5)
Turkey	Male	16 (10)	6.56 (2.0)	19.26 (4.0)	51 (24)	14.96 (2.0)	21.38 (3.7)
	Female	148 (90)	6.42 (1.7)	18.57 (5.23)	161 (76)	12.61 (2.1)	18.85 (3.5)
Iran	Male	84 (47)	8.67 (0.7)	18.41 (4.7)	283 (47)	13.95 (2.1)	21.49 (4.7)
	Female	93 (53)	8.75 (0.7)	18.40 (4.5)	324 (53)	14.22 (2.1)	21.83 (4.3)
China	Male	540 (48)	8.50 (0.5)	17.17 (2.8)	2165 (48)	13.03 (2.1)	19.61 (3.7)
	Female	580 (52)	8.55 (0.5)	16.35 (2.6)	2342 (52)	13.20 (2.1)	18.82 (3.1)
Indonesia	Male	200 (49)	6.57 (1.7)	ND	243 (41)	13.16 (2.3)	ND
	Female	206 (51)	6.39 (1.7)	ND	352 (59)	13.60 (2.2)	ND
Total[a]	Male	1742 (48)	7.35 (1.7)	17.21 (3.3)	3802 (47)	13.00 (2.2)	19.85 (3.9)
	Female	1869 (52)	7.41 (1.7)	17.09 (3.9)	4307 (53)	13.01 (2.2)	19.19 (3.5)

BMI body mass index, ND no data
[a]Includes only data of countries with available data on the presented characteristics

water to TFI was comparable between children and adolescents, except in the sample of Indonesia.

Significant gender differences in the contribution of the fluid types to TFI were observed in the individual samples, yet they were inconsistent. The contribution of water to TFI was significantly higher for females in the Belgian sample ($p = 0.0057$), whereas it was lower in the Chinese samples compared with males ($p = 0.0001$). The milk contribution to TFI was higher for females in the Chinese samples, but lower in the Indonesian sample ($p = 0.004$) than for males. The contribution of other beverages to TFI was significantly higher for females in the Chinese and Belgian sample than for males ($p < 0.0001$ and $p = 0.0026$, respectively). In the Chinese sample, females also had a significantly higher contribution of hot beverages compared with males ($p < 0.0001$). The only gender difference that was consistent across several samples was observed for the contribution of RSB to TFI: males had a significantly higher RSB contribution than females in the samples of Belgium, UK, Iran and China ($p < 0.01$ for all).

When analysing the gender difference within the two age categories, significant gender differences were also observed. Among children (Fig. 1), the contribution of milk to TFI was significantly higher among men than among women in the Brazilian sample ($p = 0.01$); however, in the Iranian sample, the effect was the opposite direction ($p = 0.005$). The Chinese females drank more hot beverages than males ($p = 0.01$). Male children in UK and China had a significantly higher RSB contribution to TFI than females ($p = 0.01$ and $p = 0.0001$, respectively). In the Belgian samples, the females had a higher contribution of other beverages than males ($p = 0.01$). Among adolescents (Fig. 2), most gender differences were observed in the Chinese sample: males had a significantly higher contribution of water and RSB to TFI than females ($p < 0.0001$ for both), whereas females had a significantly higher contribution of milk, hot beverages and other beverages (all $p < 0.0001$) to TFI than males. In the Iranian sample, adolescent males had a higher contribution of RSB to TFI than adolescent females ($p = 0.0002$).

Discussion

This unique pooled analysis of individual data of 13 cross-sectional surveys provides novel insights on fluid intake

Table 2. *Mean daily intake of different fluid types (mL/day) of children (4–9 years), stratified by country*

Country	Sex	Water	Milk	Hot beverages	Juices	RSB	Alcoholic beverages	Other beverages
Mexico	Male	424 (409)	350 (239)	23 (76)	155 (207)	424 (416)	0 (0)	15 (164)
	Female	410 (409)	321 (207)	35 (75)	157 (216)	357 (316)	0 (0)	4 (22)
Brazil	Male	536 (397)	487 (259) [a]	33 (99)	479 (335)	136 (216)	0 (0)	4 (27)
	Female	543 (317)	428 (284)	45 (106)	497 (369)	141 (239)	0 (0)	8 (42)
Uruguay	Male	751 (539)	541 (216)	11 (37)	380 (428)	406 (387)	0 (0)	40 (185)
	Female	896 (474)	603 (213)	15 (47)	388 (506)	447 (465)	0 (0)	0 (0)
Argentina	Male	312 (339)	341 (149)	99 (140)	303 (397)	582 (472)	ND	0 (0)
	Female	420 (633)	353 (180)	157 (361)	310 (368)	616 (709)	ND	2 (9)
Spain	Male	804 (549)	574 (279) [a]	37 (120)	250 (399)	119 (174)	0 (0)	ND
	Female	785 (501)	440 (264)	36 (86)	174 (159)	66 (106)	0 (0)	ND
France	Male	546 (295)	245 (159)	3 (16)	86 (94)	145 (195)	0 (0)	ND
	Female	529 (325)	245 (184)	4 (13)	95 (104)	138 (173)	0 (0)	ND
Belgium	Male	379 (293)	167 (160)	ND	139 (120)	195 (210) [a]	0 (0)	16 (33)
	Female	371 (624)	135 (149)	ND	126 (142)	138 (158)	0 (3)	25 (42)
UK	Male	529 (348)	241 (253)	31 (95)	238 (220)	652 (605) [b]	0 (0)	1 (7)
	Female	434 (297)	281 (306)	67 (142)	261 (297)	407 (363)	0 (0)	0 (4)
Poland	Male	252 (297)	164 (139)	460 (241)	191 (187)	324 (250)	0 (4)	26 (117)
	Female	267 (347)	143 (138)	472 (274)	213 (171)	263 (252)	0 (4)	7 (18)
Turkey	Male	773 (297)	268 (232)	222 (154)	86 (103)	217 (341)	0 (0)	240 (247)
	Female	851 (443)	275 (315)	207 (181)	129 (143)	113 (194)	0 (0)	159 (244)
Iran	Male	709 (347) [a]	271 (173)	137 (99) [b]	80 (86)	117 (95)	ND	2 (7)
	Female	610 (292)	288 (167)	99 (88)	70 (73)	91 (82)	ND	6 (21)
China	Male	660 (380)	185 (164)	11 (57) [a]	47 (101)	65 (114) [c]	ND	15 (40)
	Female	641 (374)	187 (157)	19 (71)	41 (82)	44 (84)	ND	19 (45)
Indonesia	Male	1387 (746)	232 (276) [b]	90 (179)	21 (70)	191 (375)	ND	18 (59)
	Female	1394 (740)	163 (249)	72 (120)	22 (73)	164 (300)	ND	10 (36)
Total	Male	651 (535)	272 (238) [b]	54 (143) [b]	144 (235)	204 (323) [c]	0 (1)	14 (83) [b]
	Female	661 (525)	247 (236)	70 (159)	140 (235)	161 (280)	0 (2)	23 (87)

Intake data presented as mean (SD) and analysed with a Student's t test
[a] p value <0.05; [b] p values <0.01; [c] p values <0.0001

countries that, to the best of our knowledge, had no internationally published data so far. Since all 13 surveys nutrient consumed in a certain country may influence fluid intake [21]. Samples of countries with a similar geographical location indeed showed similarities in the contribution of the different fluid types to TFI. All samples of Latin America, Mexico, Brazil, Uruguay and Argentina were characterized by a high contribution of RSB and juices to TFI. Argentina, however, differed from the other three Latin American countries by a larger contribution of hot beverages to TFI, more specifically the traditional Mate. The samples of the Asian countries included in this analysis (Indonesia and China) and also those from countries relatively closely located around the Mediterranean Sea (France, Spain, Iran and Turkey) had a comparable pattern: at least half of the fluid intake in these countries came from water. The contributions of the fluid types to TFI observed in the Belgian sample seemed comparable to the pattern observed in the samples of the Latin American countries. However, hot beverages were not recorded in the Belgian survey, and therefore, a comparison with other countries should not be made. Data in adult samples also showed similar contributions of the different fluids types to TFI in countries from the same geographical area [16]. This is not surprising since a number of studies have also shown that parental food preferences and nutrient intake including SSB are adopted by children and adolescents [22–24]. This observation suggests that there is a risk of relaying detrimental food and beverage intake habits between generations. This remains to be confirmed for fluid intake in the future.

Differences in the contribution of fluid types to TFI were observed between the two age groups, which have been reported by others [10, 18]. Among children, the intake of milk and juice was higher than among adolescents, whereas adolescents consumed more water, hot beverages, RSB and alcoholic beverages. In the total sample, both the volume and the contribution to TFI of RSB were significantly higher among children than among adolescents; however, when each sample was considered individually, adolescents always had a higher RSB intake than children. However, due to the significant differences in intake patterns between the samples and due to the unbalance in sample sizes of the countries, interpretation of the pooled data of the total sample should be done with caution. Nevertheless, among European adolescents aged 12.5–17.5 years, similar age effects on fluid intake were observed [18]. Özen et al. [10] also drew similar conclusions in their systematic review: milk intake was higher among children and was replaced by regular fluid/soft drinks among adolescents. They also reported that with age the intake of hot beverages and diet beverages increased.

The effect of gender on the intake of the different fluids was

Fig. 1. *Contribution (%) of the different fluid types to total fluid intake of children (4–9.9 years) stratified by country and gender with being A female and B male*

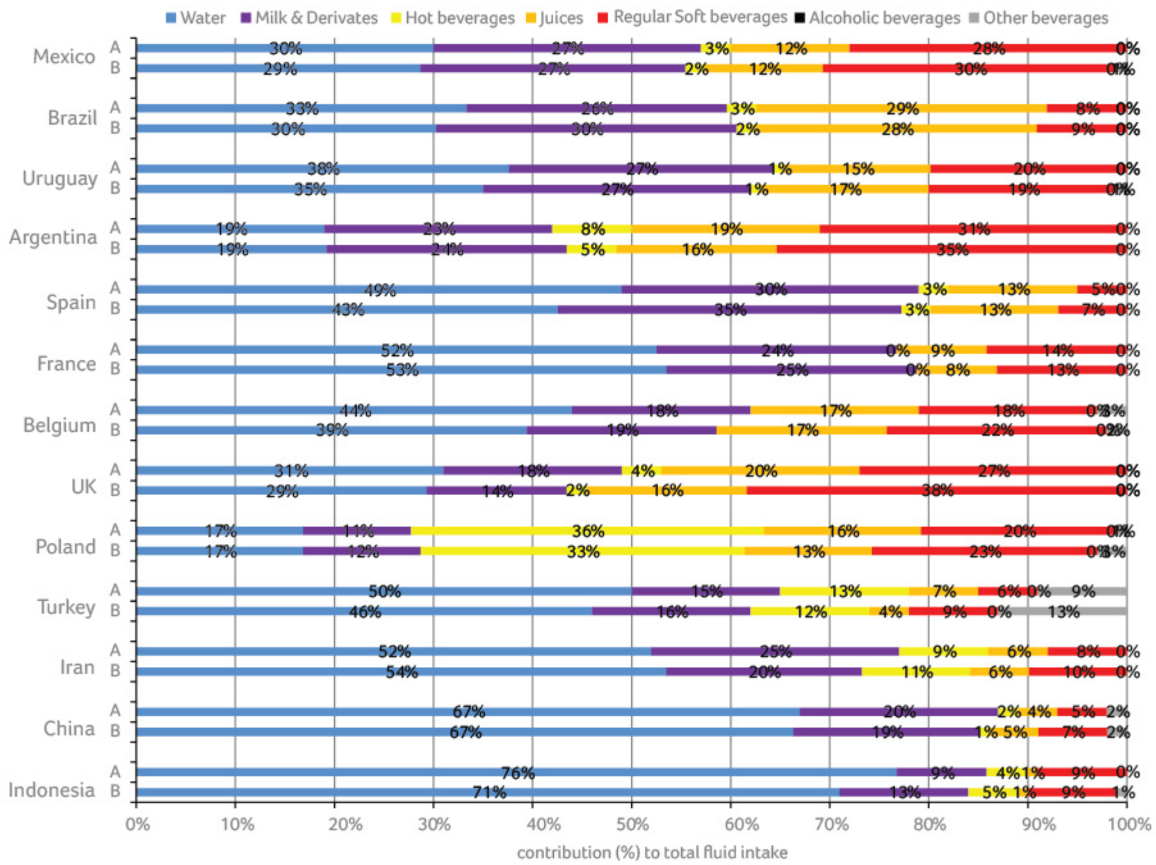
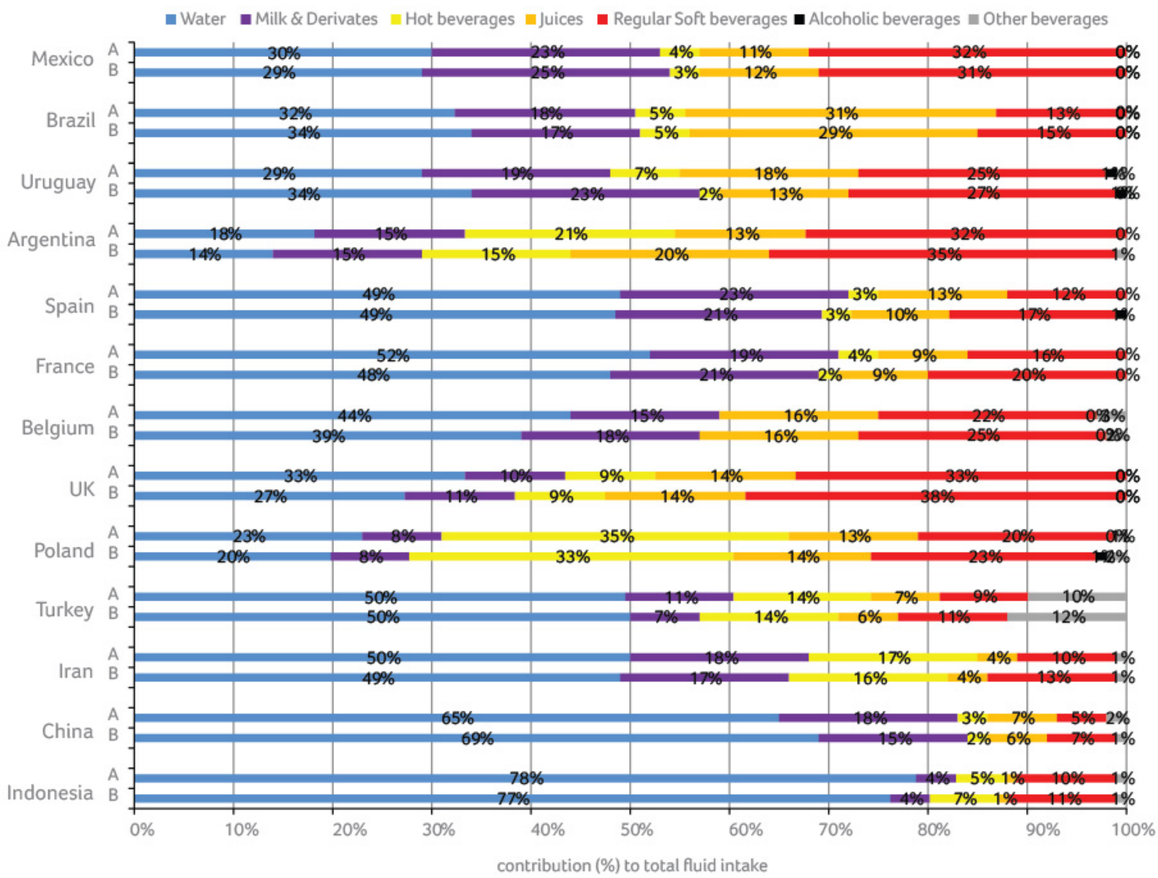


Fig. 2 Contribution (%) of the different fluid types to total fluid intake of adolescents (10–17.9 years) stratified by country and gender with being A female and B male



neither consistent nor very pronounced in the samples, except for the contribution of RSB to TFI. In four samples, males consumed more RSB than females. This observation suggests that females start adopting healthier hydration habits than males during adolescence, potentially due to an increased health consciousness or attention to their body image [25]. This lack of consistent gender effect on the intake of the different fluids was not in line with what has been reported previously. In a large European adolescent sample, males clearly had a higher contribution of high fat milk, SSB and alcoholic beverages and lower contribution of water than females [18]. The review by Özen et al. [10] reported also that males had a higher milk consumption than females. Until the gender effect on the intake of the different fluids has been analysed again by future surveys, it is recommended to interpret the gender and age effects country-by-country.

In eight out of the 13 samples included in this analysis, the combined mean of juices and RSB of both consumers and non-consumers was higher than 335 g/day. Intervention studies and cohort studies have shown that children and adolescents consuming SSB on a daily basis are at increased risk of becoming overweight or obese compared with non-regular consumers [26, 27]. Adolescent females who consumed more than 335 g/day had a greater over-all cardiometabolic risk, independent of their weight status (OR 3.2; 95 % CI 1.6, 6.2) (all p-trend ≤0.001) [27]. In light of the current prevalence of obesity and diabetes, health promotion strategies should focus, among others, on reducing the intake of SSB and increasing the intake of water. The large differences in intake patterns across samples indicate that in some countries the concern about an excessive SSB intake is higher than in other countries. Though only in three samples water was the majority of fluid intake, the concern is global.

All fluid intake data used in this analysis were self-reported. For children younger than 12 years, the primary care giver was responsible for filling the 7-day fluid record. Therefore, the risk of over- or underestimation of intake and a possible reporting error by the primary care giver cannot be excluded. In future studies, combining the recording of the intake with the collection of urine biomarkers may give an indication of the accuracy of the intake reporting. Also a validation of accuracy and reliability of the 7-day fluid record would be useful. It would also allow an estimation of the hydration status of children and adolescents. An estimate on how fluid intake contributed to the whole diet also cannot be made due to lack of food data. However, evidence suggested that a fluid-specific record might more accurately estimate fluid intake compared with a food and fluid record [28]. Since the primary aim of all 13 surveys was to assess fluid intake, the preference was given to record fluids only. Another limitation to acknowledge is that not all samples were necessarily representative of the national target sample of the country. Nevertheless, the methods of recruitment used in the surveys are recognized as valuable methods to provide enough sample by age of participants, regions of the country and different socioeconomic groups for meaningful analysis. In the future, it would also be recommended to avoid the minor differences in the fluid classification that were currently present across countries.

This pooled reanalysis of individual data has several strengths. All surveys used a fluid-specific record over 7 consecutive days and are therefore assumed to provide data highly representative of habitual daily intakes. Moreover, all records were supported by a photographic booklet to increase accuracy of the reported volumes. An additional strength is that this compilation of 13 samples of different countries allowed to highlight the large diversity in fluid intake patterns across countries. In conclusion, this analysis answers sorely to the need of data on fluid intake patterns for children and adolescents from various countries. The data indicated variability in intake patterns by age and sex. Additionally, they indicated a prevalent consumption of caloric fluids including juices and RSB. Water accounted for less than half of TFI for a large proportion of the children and adolescents. Considering that water is the preferred fluid, the data warrant further work to understand the variability across countries and to efficiently increase water intake of children and adolescents. Creating a hydrogenic environment for the child or adolescent could be one action, among others, to increase the adherence to the WHO recommendation on energy intake of free sugars.

Acknowledgments

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Conflict of interest

IG and JHB are full-time employees of Danone Research. JS-S, JS, LAM, SK, JG and HM are members of advisory board on fluid intake of Danone Research. AM and NE are employer at NNFTRI, an institution which has received a research grant from Damavand Mineral Water Company (a brand of Danone Group in Iran).

Ethical standard

The protocol of the unpublished surveys was reviewed and approved by the Institutional Review Board, Office of Research Compliance of the University of Arkansas (IRB Protocol # 14-12-376). The Belgian survey was approved by the ethical committee of the Queen Fabiola Children's University Hospital of Brussels approved (on 20 September 2011) (reference: CEH-No. 58/11). The Chinese surveys were approved by the Ethical Review Committee of the National Institute for Nutrition and Food Safety, Chinese Center for Disease Control and Prevention. Informed consent was obtained by all participating children or adolescents and their parents, as appropriate. All data were recorded anonymously.

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SITUATIONAL ANALYSIS AND EXPERT EVALUATION OF THE NUTRITION AND HEALTH STATUS OF INFANTS AND YOUNG CHILDREN IN FIVE COUNTRIES IN SUB-SAHARAN AFRICA

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Abstract

Background: The poor feeding practices of pregnant women, infants, and young children contribute to the burden of malnutrition and subsequently to childhood morbidity and mortality in sub-Saharan Africa. Gaining insight into the nutritional and health status of infants and young children will help to focus future nutrition programs and actions. Objective. To assess the nutrition and health status of infants and young children in five sub-Saharan African countries: Ivory Coast, Senegal, Cameroon, Kenya, and Nigeria.

Methods: Published and gray literature was critically reviewed and enriched with the views of local experts from academia, hospitals, and institutions to assess infants' and children's diet and health in the five sub-Saharan African countries. Subsequently, the Africa Nutriday Conference was held in Senegal in November 2011 to further discuss key challenges, action plans, and recommendations for future research.

Results: This review highlighted the need for education of parents and healthcare professionals in order to increase their knowledge of breastfeeding, vaccination programs, and over- and undernutrition. An integrated health and nutrition surveillance is needed both to identify micronutrient deficiencies and to recognize early signs of overweight. These data will help to adapt nutrition education and food fortification programs to the target populations.

Conclusions. Different countries in sub-Saharan Africa face similar nutrition and health issues and are currently not sharing best practices, nutrition programs, and scientific studies optimally. There is a need for closer collaboration among scientists within and between countries.

Introduction

The life stages of pregnancy, lactation, and infancy are periods of high nutritional demand due to rapid development and growth of the child. In sub-Saharan Africa, mortality among children under 5 years of age is high, mainly because of deaths from acute respiratory infections, malaria, diarrhea, and malnutrition [1]. Globally, well over two-thirds of these deaths, which are often associated with inappropriate feeding practices, occur in the first year of life. One of the reasons for this is that not more than 30% of infants in sub-Saharan Africa are exclusively breastfed during the first 4 months of life [2]. Complementary feeding frequently begins too early [3]. Foods are often nutritionally inadequate and unsafe because of microbiological contamination. Malnourished children who survive are frequently ill and suffer lifelong consequences of impaired development. Paradoxically, there is at the same time an increasing incidence of overweight and obesity in children. This double burden of malnutrition is a rising concern [4, 5].

Poor feeding practices are a major threat to social and economic development; thus, improving the nutritional status of women and their newborns is critical to promote development as well as survival [6]. Recent publications on the nutritional situation in sub-Saharan Africa [1, 7–10] all point to the same challenges in the region: compromised breastfeeding practices, poor quality of complementary feeding, vitamin A and iron deficiencies, lack of nutrition education and counseling, and a need for regional collaborations on nutrition and health.

In this paper we will focus on the current nutrition and health status of infants and young children in five sub-Saharan African countries (Ivory Coast, Senegal, Cameroon, Kenya, and Nigeria) to deepen our understanding of the regional issues. A critical analysis of the available literature was performed and enriched by information from local experts. To bring together the data from the region and to discuss the implications and solutions, the Africa Nutriday Conference was then held in Dakar, Senegal, in November 2011. The conference was attended by scientists (e.g., nutritionists), healthcare professionals (e.g., pediatricians, neonatologists), and institutions (representatives from nongovernmental organizations [NGOs] and governments). The outcomes of the analysis were discussed for each country and then through a transversal analysis of the five countries to identify commonalities. The key challenges were further discussed in small workshops with participants having different expertise and origins. This paper presents the methodology and main outcomes of the critical analysis and reflects the discussions of the workshops, including action plans and recommendations for future research.

Methods

Danone Research developed an analysis to describe the public health and nutritional situation of target groups within a country. This critical analysis is intended to be a first step in a long-term process to increase knowledge on concerned countries, followed by more specific field surveys (dietary surveys, food style surveys) to address knowledge gaps. The analysis consists of two complementary approaches. First, an extensive literature review is performed; this literature review

Table 1. *Overview of interviews and selected literature by country*

Interviews/literature	Ivory Coast	Senegal	Cameroon	Kenya	Nigeria
Interviews					
Total	22	12	17	15	26
Face-to-face	7	12	10	8	0
Phone	15	0	7	7	26
Total publications	23	15	21	21	30
Additional reports and others	Not evaluated	Not evaluated	17	5	Not evaluated

involves structured searches for relevant published literature using a range of healthcare-related databases (PubMed, Medline, Pascal, Web of Science) as well as gray literature obtained from international and national organizations (e.g., the Food and Agriculture Organization, UNICEF, the World Health Organization [WHO], the US Agency for International Development, the CIA World FactBook, the World Bank, and websites of Ministries of Health and NGOs). Secondly, the literature review is enriched by the views, opinions, and experience of different local experts from academia, hospitals, and institutions.

In the past 2 years, the analysis was used to assess infants' and children's diet and health in 24 countries throughout the world, 5 of which are sub-Saharan African countries (Ivory Coast, Senegal, Cameroon, Kenya, and Nigeria); these were done by a consulting agency or through collaboration with local experts. In these sub-Saharan African countries, the literature search focused on infant and child mortality, general health issues, vaccination regimes, breastfeeding practices, feeding habits, and the incidence and causes of nutritional deficiencies and excesses. General key search terms for public health and nutritional aspects in young children, women of childbearing age, pregnant women, and lactating women were combined with country-specific key words. Literature searches were limited to articles published after January 1990. Additional unpublished literature was obtained from opinion leaders and other stakeholders.

An average of 18 interviews per country were then conducted with key opinion leaders, ranging from 12 in Senegal to 26 in Nigeria (table 1). These interviews were conducted face-to-face when possible, otherwise by phone. All interviews in Nigeria were conducted by phone due to difficulties of traveling in the country.

The selection of experts was based on the following steps:

Step 1: Establishment of the most exhaustive list of relevant key opinion leaders. For this, the approach consisted of selecting key representatives of the main nutrition and public health institutions of the country (ministries, universities, associations, and hospitals and other healthcare institutions), identifying key authors emerging from the literature review, and completing the list based on local inputs obtained from key opinion leaders already involved.

Step 2: Selection of key opinion leaders, focusing on those most representative of the different forms of expertise (e.g., pediatricians, neonatologists, nutritionists, and gynecologists), responsibilities (e.g., academic professionals and healthcare practitioners), and geographic areas within the country. The interviewees were asked to provide an overview of the country's priorities, programs, and recommendations, and also to reflect on what they perceived to be health concerns, issues, and knowledge gaps related to children's nutrition and health in the country.

All data from the literature review and expert interviews were entered into a database and categorized on the basis of the following themes: general country information (e.g., population, vital statistics, and economy), infant and child health and mortality, breastfeeding practices and main feeding patterns (e.g., meal frequency and staple foods), nutritional status (e.g., local nutrient recommendations and intakes), local and national health programs, and recommendations for future research and actions.

Workshop sessions were organized in six groups on the key challenges identified in the transversal analysis: How to improve breastfeeding practices? How to improve the transition from exclusive breastfeeding to family foods? How to improve the impact of food fortification programs for young children? How to implement healthy eating habits in nutrition-transition countries? How to break the vicious circle of nutrition-related issues? How to improve the quality of mothers' nutrition knowledge?

Participants were divided into cross-functional and cross-country groups, each one dealing with two subjects. French-speaking and English-speaking participants were assigned to separate groups to facilitate discussions and sharing.

Outcomes of the transversal analysis and the workshops

Country general information

The data presented in table 2 provide a comparison of the population and growth rates of the sub-Saharan African countries examined in this study [11–13]. Population growth rates are high, and so are infant mortality rates. Although some of the countries in the region, such as Senegal, are making progress toward Millennium Development Goal 4.1 to reduce mortality among children under 5 years of age by two-thirds by 2015, the countries are still high on the list of those with high mortality among children under 5 years of age. Regionally, the probability of dying before the age of 5 years has decreased from 180 to 140 per 1,000 live births. Figure 1 shows how the five countries are progressing toward the three nutrition-related Millennium Development Goals [14–16].

The population in Ivory Coast, Senegal, Cameroon, and Nigeria is evenly distributed between urban and rural areas, as is the world's population. In contrast, almost 80% of people in Kenya live in rural areas. However, Kenya is currently experiencing rapid rates of urbanization; each year, 4.2% of the population moves from a rural to an urban area.

Sub-Saharan Africa is the poorest region in the world. The per capita gross domestic product (GDP) in purchasing power parity ranges from US$1,600 in Ivory Coast to US$2,600 in

TABLE 2. *Population characteristics of the five sub-Saharan African countries*

Characteristic	Ivory Coast	Senegal	Cameroon	Kenya	Nigeria	World
Population	21,504,162	12,643,799	19,711,291	41,070,934	155,215,000	6,928,198,253
Population growth rate (%)	2.08	2.56	2.12	2.46	1.94	1.09
Birth rate (/1,000 population)	31.0	36.7	33.0	33.5	35.5	19.2
Death rate (/1,000 population)	10.2	9.3	11.8	8.9	16.1	8.1
Infant < 1 yr mortality (/1,000 live births)	64.8	50	60.9	52.3	91.5	41.6
Children < 5 yr mortality (/1,000 live births)	114	75	149	128	138	NA
Life expectancy at birth (yr)	56.8	59.8	54.4	59.5	47.6	67.1
Rural population (%)	49	58	42	78	50	49.5
GDP per capita (US$)	1,600	1,900	2,300	1,700	2,600	11,800
Below poverty line (%)	42	54	48	50	70	NA
Access to clean drinking water (%)	80	69	74	59	58	87
Access to sanitation (%)	23	51	47	31	32	61
Children < 5 yr underweight (%)	16.7	14.5	16.6	16.5	26.7	NA
Literacy (%)	48.7	39.3	67.9	85.1	68.0	83.7

Nigeria, compared with the world average of US$11,800 (table 2). In the selected sub-Saharan African countries, 42% to 70% of the population is defined as poor and living below the poverty line. Literacy levels vary considerably in the sample countries, with the highest level in Kenya (85%), followed by Cameroon and Nigeria (68%), Ivory Coast (49%), and finally Senegal (39%). In all countries, there is gender disparity in education in favor of boys. Moreover, girls in rural areas are roughly only half as likely to receive education as girls in urban areas [17, 18].

The healthcare system in sub-Saharan Africa is generally organized and managed on three levels: national (e.g., teaching and specialist hospitals), regional (e.g., general hospitals and medical clinics), and local (e.g., health posts, dispensaries, and nursing homes). The countries face major challenges in providing universal access to health services. The high cost of medical care, lack of resources, and long distances to healthcare facilities are important problems in access to healthcare. In Kenya, Cameroon, and Ivory Coast, more than 50% of all health workers are nurses and midwives, who are the main providers of care to women throughout pregnancy, delivery, and the early postnatal period. In Nigeria and Senegal, doctors, including gynecologists,play a more important role in providing maternal and newborn healthcare. WHO recommends a minimum of four antenatal visits, consisting of pregnancy monitoring; managing problems such as high blood pressure, infections, and nutritional deficiencies; health and nutrition counseling; and vaccination. The proportion of women receiving antenatal care is relatively high in Kenya (92%), Ivory Coast (85%), Senegal (87%), and Cameroon (82%), compared with only 58% in Nigeria [19]. However, in all of these five countries, only about half of pregnant women have the recommended four or more antenatal visits [19]. The main reasons for underutilization of antenatal care in Nigeria are women's perceptions that they are healthy, disapproval by husbands, distance to health facilities, and cost [20].

Infant and child health and mortality

Diarrhea, malaria, and pneumonia are the main causes of child mortality in the selected sub-Saharan African countries (fig. 2) [21]. In cases of diarrhea, families are encouraged to rehydrate their children with either commercially packaged oral rehydration solution (ORS) or fluids prepared at home. However, the management of acute diarrhea is still not satisfactory. In Kenya, 78% of children suffering from the disease are given ORS or increased fluids, compared with 37% and 57% in Nigeria and Cameroon, respectively [17, 18, 22]. Malaria is effectively and easily prevented by using insecticide-treated mosquito nets. There is a high degree of variability in the use of insecticide-treated nets between and within sub-Saharan African countries. In Kenya, 56% of households have at least one insecticide-treated net, compared with 20% in Senegal, 8% in Nigeria, and only 2% to 3% in Ivory Coast and Cameroon. Ownership of insecticide-treated nets increases with wealth [17, 18, 22–24]. In Senegal, mortality from malaria is rapidly decreasing due to the combined use of mosquito nets, indoor spraying with low doses of insecticides, prophylaxis during pregnancy, and rapid diagnostic tests [25].

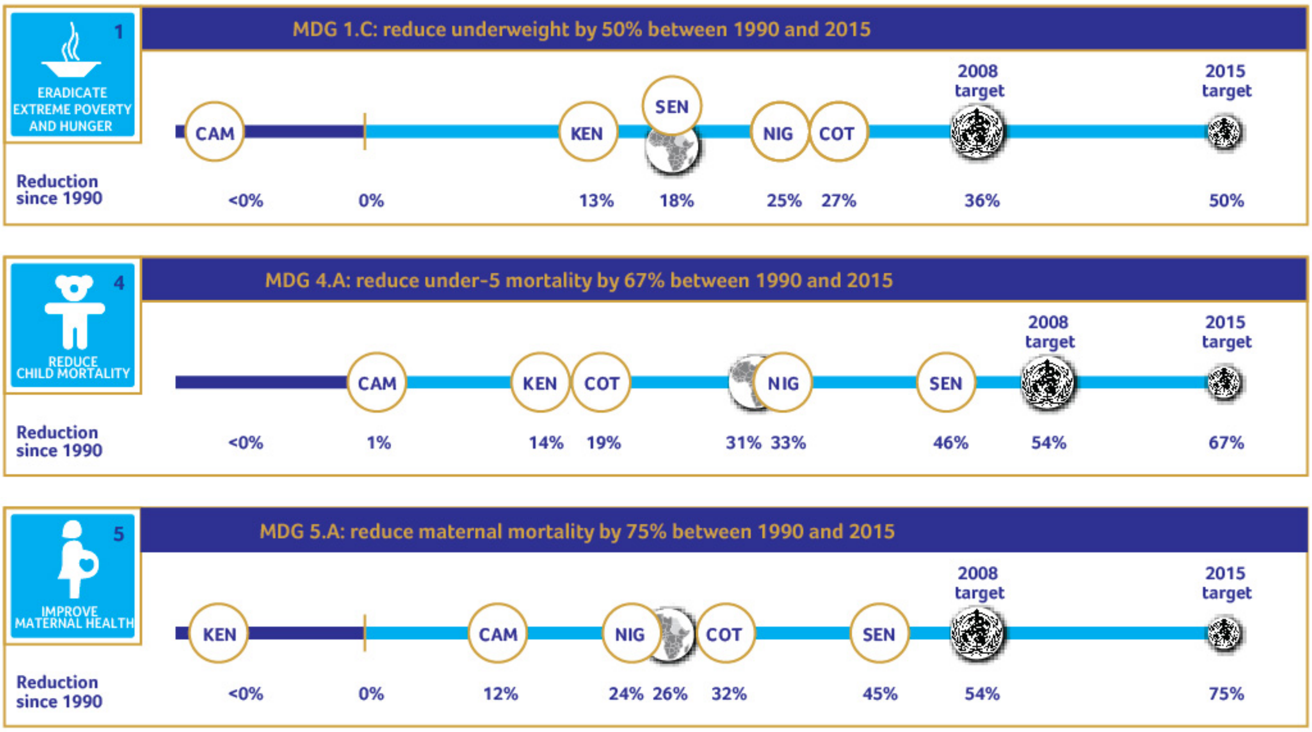
Malnutrition is the main contributor to the burden of disease, partly because it depresses the immune system. Malnourished children have a greater incidence and increased severity of persistent diarrhea, malaria, and pneumonia. Moreover, these infectious diseases also contribute to malnutrition, which constitutes a vicious cycle [26].

The WHO Expanded Program on Immunization (EPI), which was launched in 1974, has been a key tool to reduce child mortality in sub-Saharan Africa. The diseases included in the EPI in the five sub-Saharan African countries are diphtheria, tetanus, pertussis (combined in the DTP triple vaccine), measles, polio, tuberculosis, and yellow fever. Figure 3 shows the vaccination rates among children aged 12 to 23 months by type of vaccine and year [27]. Although vaccination coverage in Nigeria has increased in the past 10 years, the country is still lagging behind other countries in sub-Saharan Africa. Many children in rural areas, especially in the North, are not immunized because their parents believe that the vaccines have negative effects on their children. In Ivory Coast, immunization programs were largely disrupted because of the civil war (2002–07), leading to an increase in reported cases of measles, neonatal tetanus, and polio. Efforts have been made to revive the vaccination program, and since 2008 coverage has slowly begun to increase again.

Breastfeeding practices

WHO recommends exclusive breastfeeding during the first 6

FIG. 1. *Progress toward the three nutrition-related Millennium Development Goals (MDG) in the five sub-Saharan African countries. CAM, Cameroon; COT, Ivory Coast; KEN, Kenya; NIG, Nigeria; SEN, Senegal*



months of life for optimal growth, development, and health [28]. Breastfeeding should continue up to 2 years or later, and nutritionally adequate, safe, and appropriately fed complementary foods should be introduced at the age of 6 months to meet the evolving needs of the growing infant. Promotion of breastfeeding is seen as the most effective way to reduce child mortality [29], and it is estimated that 1.4 million child-lives could be saved by improving breastfeeding practices [30]. "Exclusive breastfeeding" is defined by WHO as giving no food or drink—not even water—except human milk. It does, however, allow the infant to receive ORS, drops, and syrups (vitamins, minerals, and medicines). Overall breastfeeding rates in sub-Saharan Africa are high. However, although exclusive breastfeeding rates in the first 6 months of life have increased significantly in sub-Saharan Africa [31] from 20% to 30% on average, the rates are still low, and a large percentage of newborns are not breastfed in the first hour after delivery. Figure 4 gives an overview of specific breastfeeding rates in the five sub-Saharan African countries, showing that the rate of exclusive breastfeeding in the first 6 months of life ranges from 4% to 34%. The rate of exclusive breastfeeding is especially low in Ivory Coast (4%) [32] and is highest in Kenya (32%) [17] and Senegal (34%) [24, 33]. However, exclusive breastfeeding rates vary widely within the countries. For example, a recent study showed that the rate of exclusive breastfeeding is extremely low (2%) in poor urban settlements in Nairobi, Kenya [34]. The total duration of breastfeeding is globally long in the five countries; e.g., in Nairobi 85% of women were still breastfeeding at 11 months [34], and the mean duration of breastfeeding was almost 18 months in Nigeria and Cameroon and 20 months in Ivory Coast, Kenya, and Senegal [17, 18, 24, 32, 35].

Reasons for discontinuing breastfeeding, as indicated by mothers, are not enough breastmilk, mother going to work, and advice of healthcare professionals. The Baby-Friendly Hospital initiative (BFHI), launched in 1991, is an effort by UNICEF and WHO to ensure that all maternity facilities, whether free-standing or in a hospital, become centers of breastfeeding support [9]. The analysis showed that the BFHI, supported by local associations, has a real impact on breastfeeding practices in sub-Saharan Africa. Similarly, when the initiative was interrupted, breastfeeding rates generally declined. For example, breastfeeding rates dramatically decreased in Ivory Coast due to the civil war from 10% to 4% and went down in Nigeria due to the transfer of BFHI responsibility from UNICEF to the state [36].

In many young infants breastfeeding is combined with the consumption of water, tea, fruit juice, regular cows' or goats' milk, coffee, and other liquids (fig. 4). Mothers generally follow traditional practices and are usually unaware of the possible negative effects of cofeeding liquids on the risk of malnutrition and infection for their child.

FIG. 2.*Main causes of death among children under 5 years of age in the five sub-Saharan African countries in 2008*

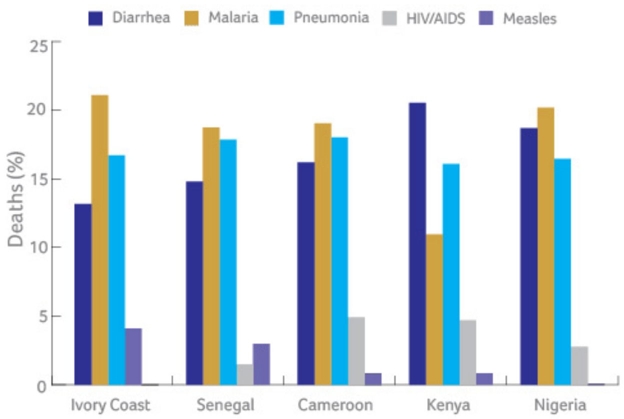


FIG. 3. *Vaccination rates for (A) tuberculosis and bacillus Calmette–Guérin (BCG), (B) third dose of diphtheria–tetanus–pertussis mixed vaccine (DTP3), (C) third dose of oral poliovirus vaccine (Pol3), and (D) measles vaccine (MCV) by country and year*

Another harmful practice is that infants are not always breastfed in the first hour after delivery. The proportion of infants that were placed to the breast in the first hour was 25% in Ivory Coast, 23% in Senegal, 20% in Cameroon, 60% in Kenya, and 32% in Nigeria. These low rates can be explained by the widespread belief in sub-Saharan Africa that colostrum is dirty and by mothers' limited knowledge of the immunologic advantages of early breastfeeding [37]. It is estimated that 5% of adults in sub-Saharan Africa are infected with HIV [38]. Recommendations for optimal feeding methods to prevent mother-to-child transmission of HIV have recently been revised [39]. Until recently, WHO advised HIV-positive mothers to avoid breastfeeding if they were able to afford, prepare, and store formula milk safely. However, recent evidence, especially from South Africa, showed that a combination of exclusive breastfeeding and the use of antiretroviral treatment can significantly reduce the risk of transmitting HIV to babies through breastfeeding. Based on this evidence, the new recommendation on infant feeding by HIV-positive mothers is that the HIV-positive mothers or their infants take antiretroviral drugs throughout the period of breastfeeding and until the infant is 12 months old. This means that the child can benefit from breastfeeding with very little risk of becoming infected with HIV.

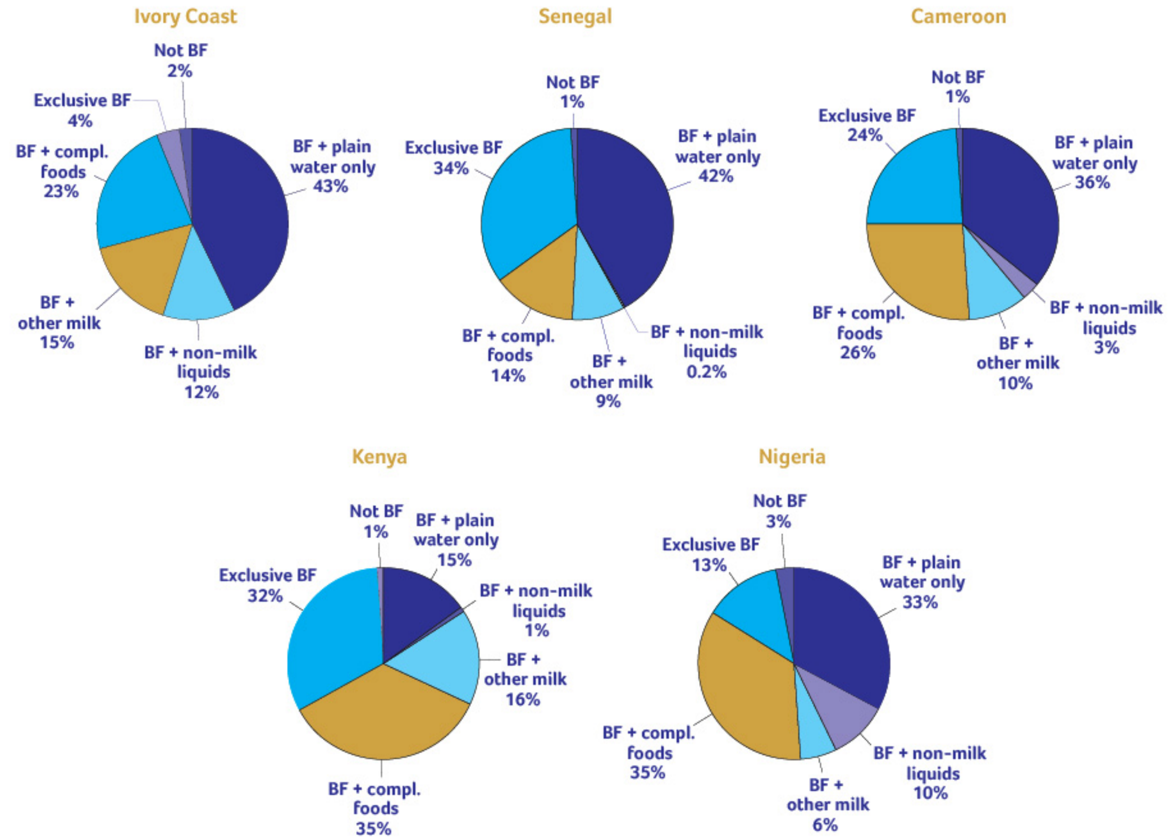
The analysis we did in the five sub-Saharan African countries indicates poor adherence to WHO recommendations for breastfeeding. In the workshop. the question "how to improve breastfeeding practices" was addressed. Three categories of opportunities were identified:

- Convince and involve: convince local policymakers of the danger of nonexclusive breastfeeding and show them the need to prioritize. Create a Government and Support Group (i.e., relevant stakeholders such as health professional associations, NGOs, Ministry of Health) to build relevant and realistic solutions to improve breastfeeding practices.

- Information and education: re-energize the breastfeeding initiative. Involve healthcare professionals in a more aggressive communication on the issue and thereby increase the impact of the message. Make sure that education starts early during antenatal care. There was optimism about the possibility of overcoming negative cultural practices with active involvement of healthcare professionals such as midwives.

- Approach peer educators: identify the influencers (e.g., mothers, neighbors, mothers-in-law) to create a protective environment. Make use of female social networks (e.g., national women's organizations) to promote breastfeeding.

FIG. 4. *Breastfeeding (BF) rates and practice in the first 6 months of life in the five sub-Saharan African countries*



Feeding habits

After the 6th month of life, exclusive breastfeeding is no longer sufficient to meet the nutritional needs of the growing infant. Well-adapted complementary foods should be given to help the infant gradually make the transition to an adult diet. Lutter et al. [40] indicated that infant and young child nutrition will only improve if activation of breastfeeding practices, increased sanitation, and health improvements are combined with improvements in complementary feeding behavior. WHO recommends introducing safe and nutritionally adequate complementary foods from the age of 6 months. It was shown in a review by Onyango in 2003 [41] and now confirmed in our analysis that many infants in sub-Saharan Africa begin to receive cereal-based foods well before this age. The mean age of introduction was around 2 months in Nigeria, Kenya, and Senegal and 4.5 months in Cameroon [17, 18, 24, 35].

Two strategies of complementary feeding were identified. In Kenya, complementary foods consist mainly of adult-type diets introduced in an adapted portion size. In the other countries, complementary foods usually consist of specific child-adapted meals, but these foods are monotonous and bulky. In both cases, cereals, roots, and tubers account for a large percentage of the energy intake of infants and young children. The specific staple foods used, such as maize, millet, sorghum, and cassava, vary between and even within countries. For infants and young children, gruel and porridges are prepared from these staples, sometimes accompanied by fruits and legumes. Most affordable carbohydrate staples are limited in their protein and micronutrient composition. They often contain antinutritional factors (such as phytates) that reduce the bioavailability of micronutrients. Animal-source foods (milk, fish, meat, eggs, or milk-based products), which are high in proteins and fats, are only occasionally part of the diet [41]. As a result, the diets do not supply sufficient amounts of energy, essential fatty acids, and micronutrients for infants and young children.

The nutritional recommendations as issued by WHO are locally translated into food-based dietary guidelines. However, the guidelines are either not well adapted to the country's situation or not implemented. From the experts in our analysis, we understood that they do not refer to local traditional foods. Other major barriers are the poor (seasonal) availability of foods, their high price, and the difficulty of implementing the guidelines due to specific cultural behaviors. Mothers are often confused about what to give their babies as complementary foods and prefer to stick to traditional practices. In addition, it was indicated that most healthcare professionals are not updated or trained on the nutritional guidelines and rather rely on their initial training. Lack of time and interest from healthcare professionals is another frequently mentioned problem.

Specific cultural habits and food taboos may play a role. For example, it is common that the youngest child in the family takes the last and smallest portion if egg, fish, or chicken is part of the meal. In some parts of Cameroon, children are not allowed to eat eggs because of a belief that it will lead to children's stealing in later life.

In one of the workshop sessions, improvement of the transition from exclusive breastfeeding to family foods was discussed. Several opportunities were identified:

- Availability and accessibility of dedicated foods: push industry for small portions of adapted products that are affordable and create quality standards through the Ministry of Health.

- Create a national and international supporting base to influence decisions: local platforms dedicated to infant nutrition and a Pan-African Science and Nutrition Society.
- Make use of existing traditional products: use food demonstrations to show how local foods can be used to improve nutritional status.

Incidence and causes of nutritional deficiencies

Eradicating hunger is part of Millennium Development Goal 1. Overall, there has been insufficient or no progress in the region toward Millennium Development Goal 1.8: to halve the rate of underweight among children under 5 years of age between 1990 and 2015. WHO indicates that the total number of undernourished people has been rising for the past decade, mainly due to population growth. Increased food prices leading to income loss, local conflicts, and climate change are seen as other important causes. Stunting rates in Africa have remained around 40% since 1990, and little improvement is anticipated according to the WHO [42]. In our analysis, we found the highest prevalence rates of both stunting (height-for-age) and underweight (weight-for-height) in Nigeria: 27% and 57%, respectively [18]. Infants between 6 and 9 months of age in rural areas are especially affected. The possible effects of living in an urban environment on nutritional status were studied in detail by Kennedy et al. [43]. They concluded that differences in the prevalence of stunting were largely due to differences in wealth and not simply due to disparities between urban and rural regions.

Findings from the Nutritional Collaborative Research Support Program (CRSP) in Kenya, for example, demonstrate how the etiology of the early onset of stunting varies among populations in varying biological, environmental, and cultural circumstances [44]. In Kenya, the problem has its origin in prepregnancy and pregnancy. Maternal size upon entry into pregnancy and weight and fat gain during pregnancy and lactation are powerful determinants of an infant's size at birth and during the first 6 months of life.

Nutritional deficiencies are widespread in sub-Saharan Africa. In our analysis, and confirmed by Drorbaugh and Neumann [10], vitamin A and iron deficiencies continue to be the main deficiencies in the region. The most common deficiency in children under 5 years of age is iron deficiency. It is estimated that 7.6 million children in western Africa are anemic, and rural households are especially at risk [45]. Both vitamin A and iodine deficiencies have decreased significantly due to prevention programs. The prevalence of zinc deficiency among children under 5 years of age in Nigeria is reported to be 20%. Information from the other four countries is lacking, but the experts consulted suspect a high prevalence. One of the experts attending the conference indicated that there seems to be an overall lack of information on the intake of essential fatty acids in the sub-Saharan African countries.

As already discussed, there is a strong relationship between infectious diarrhea and malnutrition. At the same time, it is known that infants born of obese mothers have an increased risk of developing metabolic disease later in life. These complex interrelationships were discussed in one of the sessions of the workshop: "how to break the vicious circle between nutritional status and child disease." It was indicated by the groups that more research is needed to better understand some of the relationships. Some opportunities were seen:

- Implement an integrated management of child disease, with a focus on improved access to care and medication and extended vaccination programs. Use of zinc supplements in case of diarrhea. More focus on possible hidden micronutrient deficiencies, such as iron deficiency.
- Improve education of the population, including healthcare professionals.
- Define a specific nutrition and health strategy for preterm infants.
- Develop affordable products that can help overcome the nutritional problems.

Food fortification is implemented via habitual foods such as wheat, oil, sugar, and salt. Iodized salt and wheat fortified with zinc are used in Kenya and Cameroon. In Ivory Coast, fortification of cereals is part of the Infant and Young Children Nutrition Program (IYCNP). The program aims to increase awareness of optimal nutrition among mothers and healthcare professionals and to improve access to high-quality complementary foods. The program started in 2009 and will be evaluated in 2014 [46]. In 2011, the IYCNP activities in Burkina Faso and Senegal were evaluated [47, 48]. It was concluded that promotion of exclusive breastfeeding up to 6 months of age and vitamin A supplementation should continue to get attention and national coverage. Regarding the efficacy of fortification programs, several problems are faced, according to the experts we consulted. The right type of food is not always chosen, and coverage is not always nationwide, lacking the capacity to reach the whole population of young children. The duration of the programs is not always optimal for effectiveness, and program evaluation is lacking.

Some micronutrient deficiencies, such as those of calcium and vitamin D, are less studied but may deserve attention. These deficiencies should be studied especially in women of childbearing age to prevent negative effects on the fetus and the infant during pregnancy and lactation. Supplementation might need to start early. Possible deficiencies of vitamins B2 and B12 were mentioned by many experts. Chromium deficiency, resulting in glucose intolerance, may occur in infants with protein–calorie malnutrition [49]. This was seen in Nigeria, a country with a high prevalence of type 2 diabetes mellitus.

The workshop also discussed how to improve the impact of food fortification programs to young children, specifically with respect to iodine and other nutrients. Several barriers were identified: the price of iodine, lack of control of supply in rural areas, lack of local interest to produce fortified palm oil, lack of knowledge of the optimal storage conditions of commercial fortified products, and cultural barriers (e.g., no negative perception of goiter). The following opportunities were identified:

- Increase access to fortification via the normal food. Use base foods (like flour), produce locally, and subsidize the nutrients.
- Adapt to the target population: base the fortification on thorough dietary and nutrient intake data and take cultural habits into account; improve the nutritional education of the communities.
- Partner with industry and all governmental partners (e.g., ministries of health, agriculture, and finance).

The rising problem of obesity

Many low- and middle-income countries are now facing a double burden of disease. Where the problems of infectious disease and undernutrition are still very common, they also deal with noncommunicable disease risk factors such as obesity and overweight. It is not uncommon to find undernutrition and obesity coexisting within the same country, the same community, or the same household [50]. The prevalence of overweight is rising in sub-Saharan Africa and reaches 25% to 30% among women of childbearing age [17, 18, 24]. Few data are available on the actual rates of overweight and obesity in young children. However, the available data show a prevalence of overweight of up to 6% among those under 5 years of age [51, 52]. Transition to a more Western-style diet, as well as some cultural aspects, underlies the rise. General access to food has increased, and the costs of sugar and fat are lower than those of nutritionally more healthful foods. An increased consumption of snacks was observed in our analysis. In addition, chubby infants are seen as healthy infants, and in some regions women will aim to increase weight before marriage.

The workshop discussed how healthy eating habits can best be implemented in nutrition-transition countries. The following opportunities were identified:

- Change individual behavior (nutrition and physical activity) by communicating about good habits, especially to the urban population, starting early at school, and using modern media, for example, with promotions by famous sports heroes.
- Change the image of overweight in the population. Overweight is still seen as a sign of wealth and prosperity. Educate healthcare professionals and stimulate early detection of signs of overweight.

Conclusions and recommendations from the workshops

The starting point for the African Nutriday Conference was a critical landscape analysis of the current health and nutrition situation in five sub-Saharan African countries, enriched by the views of local experts. Although we actively searched for unpublished information, we might have missed some. Experts were selected by the steps described in the Methods. It was not possible to interview all of them individually, but in the conference we gathered 31 experts from the region. In the workshop sessions, data from the transversal analysis and knowledge of the local experts were used to deepen our understanding of the nutrition and health issues that are faced by infants and young children in sub-Saharan Africa. Most of the opportunities and prioritized actions are described above. The following main calls for action were identified:

- A need for improvement of the nutrition education of both mothers and healthcare professionals was identified. This was reported in all sessions. One of them was specifically dedicated to the topic and revealed the need for more efficient parental education. Focus should be on both the mother and the father, on antenatal education (e.g., via midwives), and on the use of new media (mobile phones, radio, and television). Women can be accessed in churches or other places of worship, family meetings, and women's associations.
- Breastfeeding habits in sub-Saharan Africa are still far below the target. The rate of exclusive breastfeeding is low and could be improved by dedicated education of local healthcare professionals on the important role of colostrum in the early phase of life and the adverse effects of early introduction of liquids in the infant's diet.
- A need was identified for affordable fortified foods that can be integrated easily in local feeding habits. The participants saw a role for industry to develop fortified foods, as long as strict regulation of the quality of the foods is applied.
- An integrated health and nutrition surveillance is needed in which there is sufficient attention to identifying micronutrient deficiencies and recognizing early signs of overweight.

As a final point, the audience of the African Nutriday Conference was ready for the establishment of a Pan-African Science and Nutrition Society. The experts from the different countries realized that they were facing similar nutrition and health issues and were not sharing best practices, nutrition programs, and scientific studies optimally. The need for a closer collaboration among scientists within and between countries was clearly highlighted.

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