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The Contribution of Solid Food on Total Water Intake in 3-13 y Children

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"The Contribution of Solid Food on Total Water Intake in 3-13 y Children"

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Abstract

Introduction: Adequate hydration is important element of good health. Several studies indicate that the majority of kids are hypohydrated and do not meet dietary water intake guidelines. Some scientist also suggest that good hydration might be achieved by large consumption of food that are rich in water (i.e. fruits and vegetables). However, the information of food consumption on total water intake in children is limited. **Purpose:** We evaluated the contribution of water from solid food on total water intake in children. **Methodology:** For this cross-sectional study 81 children (35 female) 3 to 13 years old were randomly recruited to participate. Detailed food and liquid diet for two days was recorded. The nutritional analysis software NDSR was used to calculate water intake and data are presented as average of the two days. **Results:** Data showed that 50 out of 81 participants (62%) did not meet Institute of Medicine's (IOM) total water intake guidelines. Children who met IOMs recommendation drank more total water (2,527±694 ml) than the ones that did not meet the guidelines (1,315±375 ml, $P<0.05$) and more plain water (1148±630 vs. 485±324 ml, $P<0.05$). The amount of water from food consumed from kids that met and did not meet the IOM dietary guidelines was not different (523±256 vs. 416±203 mL, $P<0.05$). Food moisture ended up contributing to 32±15% of total water intake for those who did not meet the guidelines, and 21±8% for those who met them. Total water intake was strongly associated with plain water intake ($R^2=0.60$, $P<0.0001$), but weakly associated with water from food ($R^2=0.18$, $P<0.0001$). **Conclusion:** Even though the data indicated that water content of solid food contributed 28% of TWI, water from food was not different between the kids that met or did not met the dietary water guidelines. Also, higher plain water intake was associated stronger to

total water intake than water from food. Our data might indicate the water from solid food is not a very strong determinant of appropriate water intake.

Introduction:

Proper hydration is a crucial component of healthy lifestyle along with adequate nutrition and regular exercise. Even though more than 50% of the human body is consisted of water, it is often overlooked (8). Water participates in a wide range of metabolic and physiological functions. It is critical for many chemical processes such as energy production, thermoregulation and nutrient absorption around the body (8).

Water is constantly fluctuating and its excretion is made through a number of pathways including feces, sweat, and urine (5). In order to prevent dehydration, the fluid lost must be constantly replaced. Dehydration can cause a variety of negative physiological symptoms. This can include insufficient urine volume which is necessary to excrete solutes, and can increase the amount of fluid retention hormones (13). Increasing water intake is a well-accepted method for reducing the risk of kidney stones (6). The physiological mechanism behind this is that increasing water intake lowers the overall saturation of calcium oxalate, calcium phosphate and uric acid in the kidneys (7).

Water intake and good hydration is especially important for children. Children are at a high risk for dehydration considering they have a higher dependence on adults to provide the water for them. When the children are not being constantly supervised, this can lead to an increase in dehydration rates. Children often forget to consume water, and may not know the reasons that it is beneficial for them. Dehydration has been linked with impairment in cognitive function in children (8), while increase in water intake can lead to improvement in short-term memory (11).

There are several methods to determine whether an individual is properly hydrated. In a laboratory setting, a sample of urine can be acquired and measured for urine osmolality. This measures the amount of solute particles contained in the urine. The less solute in the urine, the more hydrated the individual. When the osmolality is increased, water will move out of the cells leading to cellular dehydration (8). When extracellular dehydration occurs, the brain is stimulated to release vasopressin. Vasopressin decreases the level of urine production, which increases the amount of water retention in the body (8). Urine osmolality greater than 800 milliosmoles per kilogram represents dehydration (1). This technique can sometimes have flaws because if an individual consumes a large quantity of water in a short period, urine osmolality will be low and urine color will be light but they aren't actually properly hydrated. Their body will excrete excess water before the body can use it to hydrate itself (1).

Hydration status can also be assessed based on urine color. Urine color is simple, practical, inexpensive and valid techniques for adults, kids and pregnant or lactating women (9-10). Dr. Armstrong and his colleagues developed an 8 color urine color scale ranging from very pale yellow (color 1) to dark brownish (color 8). The greater the number the more dehydrated the individual is. For hypohydrated individuals, assessing urine color has an accuracy level of determining hydration state of ~90% (9). This was measured by determining the association between urine color and urine osmolality. It was determined that a score of 3 or greater on the urine color scale was indicative of hypohydration (9).

In order to maintain euhydration, there needs to be sufficient water intake. According to a study conducted by as part of the National Health and Nutrition Examination Survey, moisture from food contributed to on average 21% of the total water intake in American adults (1). The type of food individuals consume can be due to a variety of factors: climate, cultural factors, economic status and especially age (1). This itself can lead to different levels of hydration. What is quite fascinating is that the total water intake coming from food moisture differs from country to country. For example, individuals from China have a contribution of 40% of total water intake coming from food moisture (3). These drastic differences can likely be linked to the typical diet of each country.

Different types of food have different amounts of water. Cucumbers and lettuce can have approximately 96% water, while more complex foods such as cookies can have as little as 3% water (3). This would lead to the assumption that consumption of foods with a large percentage of moisture would increase the total water intake coming from solid foods and lead to higher state of hydration.

Montenegro-Bethancourt, Johner and Remer conducted a research study about the contributions of fruit and vegetables to hydration states. Consuming fruit and vegetables with high food moisture will contribute nearly the same to total water intake as ingesting beverages that are not water (4). The water content in most fruits and vegetables is 70-95% water; while in most beverages (that are not strictly water) contain 85-100% water. (4). Free water reserve refers to the balance between available body water and the water requirements of the individual. According to this study, children who consumed more fruits and vegetables had a significantly higher free water reserve than children who consumed less (4).

Table 1: Dietary guidelines for water intake by the Institute of Medicine

	Female		Male	
	Liters	Ounces	Liters	Ounces
1-3 years	1.3	44.0	1.3	44.0
4-8 years	1.7	57.5	1.7	57.5
9-13 years	2.1	71.0	2.4	81.2

Dietary Reference Intakes recommends children age 4-8 consume 1.7 L of water per day (12). They recommend females age 9-13 to consume 2.1 L of water per day, and males age 9-13 to consume 2.4 L of water per day (12). Children aged 3-8 only consumed 1015 mL of water from beverages with food moisture contributing 431 mL of water (2). Averaging both male and female data, children aged 9-13 consumed 1254 ml of water through beverages and 457 mL of water through food moisture. This would mean that on average children aged 3-8 only consumed 85% of the recommended value of water and children aged 9-13 only consumed 81% of the total water their body needs (2).

Insufficient water intake and under hydration is well documented in children. 83% of girls and 85% of boys fail to meet the DRI requirements in consumption of water (2). This is an astounding number that could have health implications. Adequate health and hydration at a young age is a necessity for proper development. Therefore, the aim of this study is to examine the contribution of solid foods to the total water intake in children aged 3-13 and its effect on hydration. We hypothesized that children who consume more fruits and vegetables will have a higher hydration state.

Methods:

81 children (35 female) 3 to 13 years of age will be recruited to participate in the study. These individuals must be relatively healthy and not be on medication that interferes with water metabolism. During the initial meeting, the participants and their parents will be given detailed instructions of the procedure of this study. Their parents are asked to sign the consent forms and fill out documents of their medical history, and socioeconomic status. Their height (sitting and standing) and weight were measured and recorded to the closest cm and kg respectively. The participants take a detailed food and liquid log all weekend. This includes the type and quantity consumed. If the type of food they consume comes in a container or package, they must keep the package in a bag to bring back with the dietary records. The package is analyzed for its nutritional content and is added into the data pertaining to food consumption.

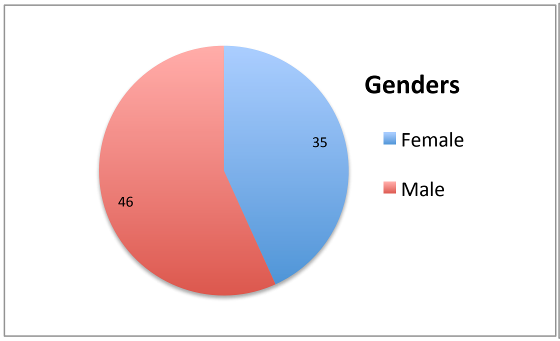
Food diaries will be inputted and analyzed by nutritional analysis software NDSR (Minneapolis, MN). This combined with the participants hydration log will indicate their total water intake for a 24 h period.

Statistical Analysis

Data will be presented by descriptive statistics (means and standard deviation) and the contribution of solid food to hydration will be assessed via regression analysis with 24 h urine osmolality. Data analysis will performed via JMP Pro (version 13, SAS Inc., Gary, NC, USA).

Results

Overall, 85 children were recruited to participate in the study across the Northwest Arkansas area. Of those, 81 had all the documentation needed to be included in the analysis (35 female). The average age of the children was 7.1±2.9 years (girls 6.9±2.9 and boys 7.3±2.9). 71 participants weight and height were measured.



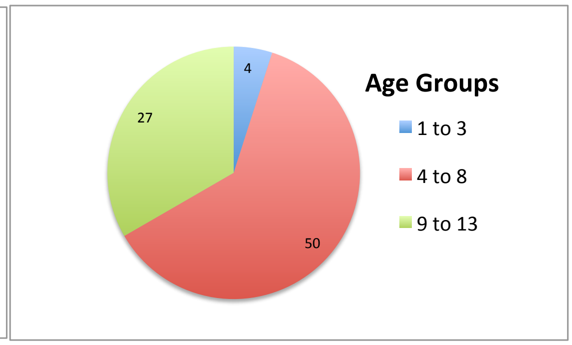


Figure 1 and 2: These graphs depict the demographics of the children participating in this study, age group and gender. Girls mean weight was 28.8±15.9 kg and height was 122.2±20.7 cm. Boys mean weight was 28.2±11.3 kg and height was 126.3±17.8 cm.

Table 2: This table depicts the demographics of the children participating in the study, shown in groups of either meeting IOM's guidelines for total water intake or not.

	Gender			
	Female		Male	
	Not Meet	Meet	Not Meet	Meet
Age (y)	6.4±3.0	7.6±2.7	7.2±2.7	7.4±3.3
Weight (kg)	23.5±10.5	36.6±19.5	27.4±9.9	29.6±13.8
Height (cm)	114.9±16.3	132.8±22.5	125.3±16.8	128±19.9

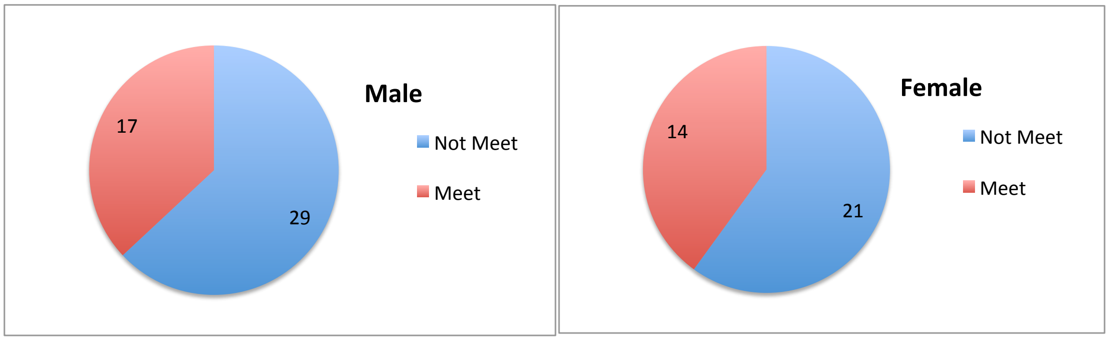


Figure 3 and 4: These graphs illustrate the number of individuals who either did or did not meet IOM's DRI, split into female and male categories.

Of the 81 participants, 50 did not meet the Institute of Medicine's (IOM) dietary reference intake (62%). Those who did not meet these guidelines had significantly less total water intake than those who did (1315.1±375.4L vs. 2527.1±694.4L, $P<0.05$).

There was a slight difference between female and males complying with the overall guidelines. A total of 40% of the females met the dietary guidelines (2558.4±704.9), while 37% of males met them (2501.3±706.4). Both male and females (4-8 years) overall mean water intake was less than the recommended 1.7L (1.607 ±503.5L and 1507.9±762.7L, respectively). Also, males (9-13 years) overall mean was less than the recommended 2.4L (2185.5±887.5).

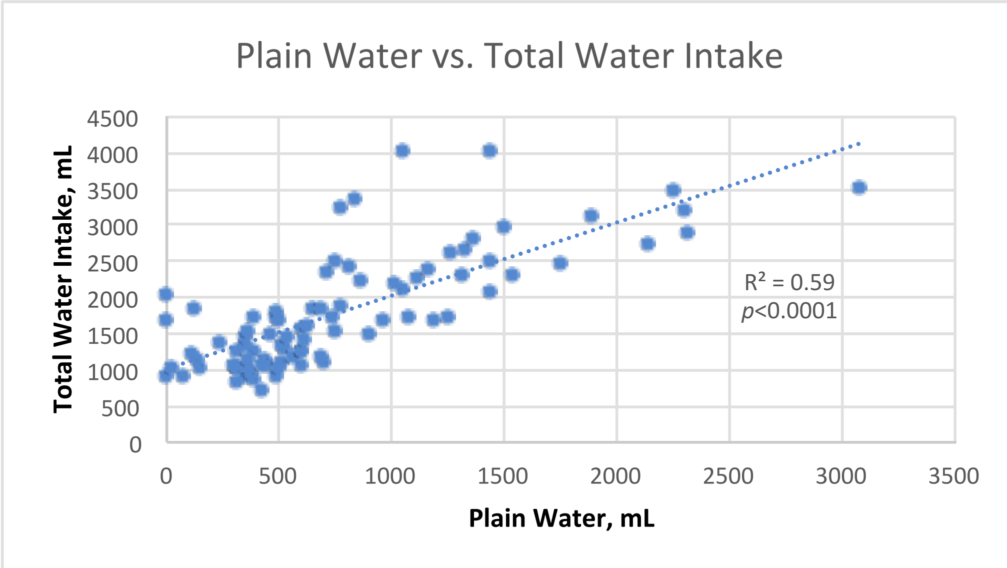


Figure 5: This graph depicts the relationship of consumption of plain water on the individuals total water intake

Pure water contributed 41% (738.9 of 1778.9) of total water intake for all participants. More specifically, for those who met the IOM guidelines, pure water contributed significantly more (43%) than those who did not meet the guidelines (37%). A calculated value of R^2=0.58543 indicates that there is a strong association with pure water consumed and total water intake.

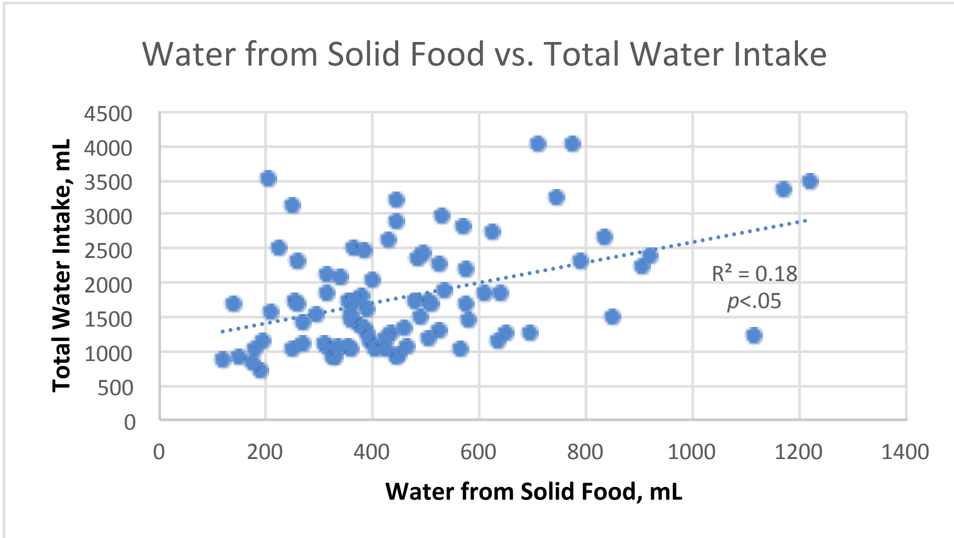


Figure 6: This graph depicts the contribution of solid foods moisture on total water intake.

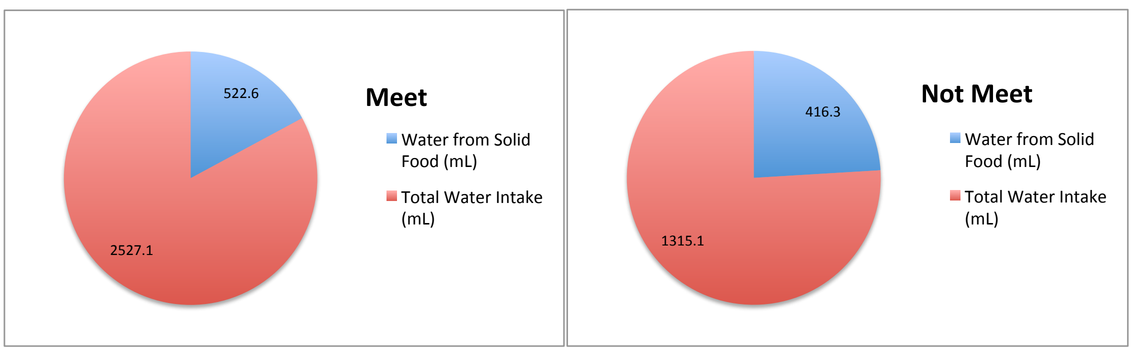


Figure 7: This graph illustrates the portion of total water intake coming from solid foods.

Those who met IOM's guidelines consumed more water through their solid food (522.6±694.4) than those who did not (416.3±202.9). However, food moisture contributed less to individuals who actually met the guidelines (21% versus 32.4%). With an R^2 value of 0.17887, this shows a poor association with total water intake.

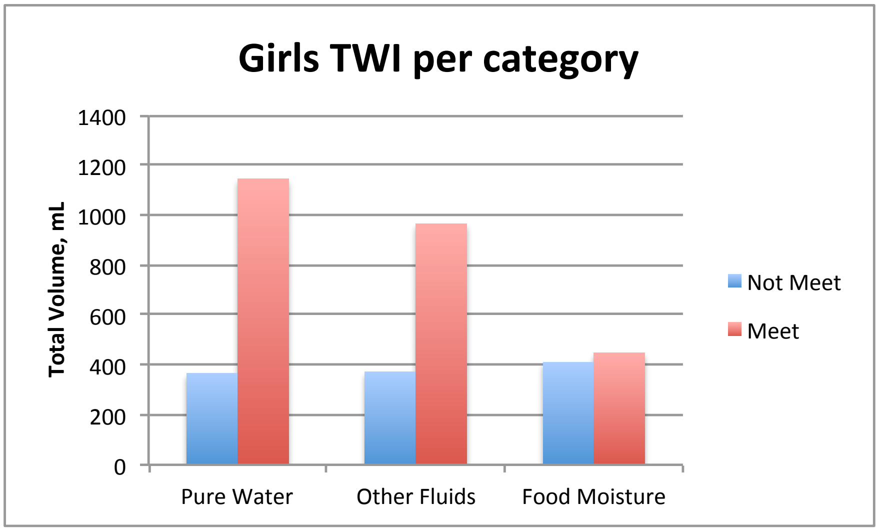


Figure 8: This graphs shows what contributes to girls total water intake in those who meet IOM's DRI and those who do not.

Individuals who met adequate intake consumed more plain water than those who did not meet the guideline entire total fluid intake. Females who met the guidelines consumed 1144.7±744.2 ml of pure water and had a total fluid intake of 2110.1±635.4 ml, while those who did not only consumed 366.3±171.4 ml of pure water and 738.6±191.5 ml of total fluid.

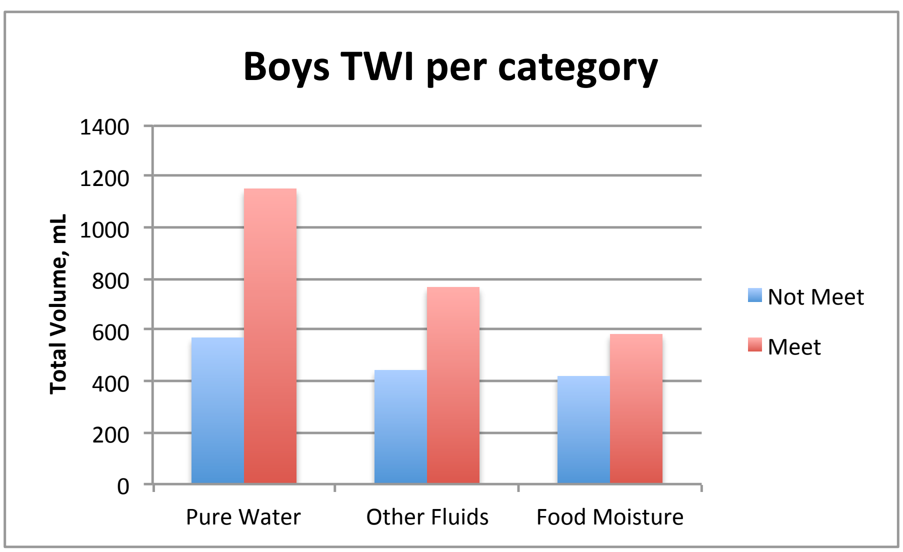


Figure 9: This graphs shows what contributes to boys total water intake in those who meet IOM's DRI and those who do not.

Males who met the guidelines consumed 1150.7±542.8 ml of pure water and 1917.5±620.6 ml of total fluid, while those who did not consumed 571.3±380.0 ml of pure water and 1014.8±408.9 ml of total fluid. Males who did not meet the guidelines consumed 47% less total fluid than those who did, while females consumed 65% less. Individuals who met the guidelines also consumed more liquids that were not water than those who did not meet them (856.5 ml vs. 413.6 ml)

Boys had slightly higher total water intake than girls (1828.8±743.1 vs. 1713.4±846.6). Like wise, boys consumed slightly more water from their solid food than girls (457±229 vs. 426.3±203.2). Both male and female had 28% of TWI coming from solid foods. The age group that had the greatest percentage of TWI coming from food moisture was both girls and boys aged 4-8 (29.3±11.7% and 30.4±15.7%, respectively). While the age group with the lowest percentage was both girls and boys aged 1-3 (23.1±13.9% and 15.1±1.9%, respectively).

Discussion

The purpose of this analysis was to determine the contribution of solid food on total water intake in children. Our data determined that 28% of total water intake comes from food moisture. This number is in the range of NHANES estimated percentage that food moisture contributes 25-30% of total water intake in children (2). The European Food Safety Authority estimated that 20-30% of total water intake comes from food (14).

In China, it is estimated that more than 40% of total water intake comes from food moisture and in Mexico 34.5% comes from food moisture.

It is clear that different cultures typical cuisine may cause variation in the percentage of contribution of food moisture. Different food contributes to total water intake in different ways. For example, a common fruit children eat is apples, which have 86.2 g of water/100g, while shortbread cookies only have 3.5 g of water/100g (16,17). Even though there is a significant difference in amount of water in each type of food, according to our study it does not seem to matter too much.

The importance of what contributes most to increasing TWI is clear in both this study and in other literature. Looking at the statistics obtained in this study, it is evident that individuals who consumed more liquids had a higher TWI. Food moisture contributes very little to overall TWI. There lacks a significant difference in percentage of water intake coming from food between those who meet the recommendations and those who do not. Though food moisture is still an important factor in hydration (still contributing nearly 30% of fluid to TWI), this analysis demonstrates that those who had a low liquid intake did not compensate by consuming more water through food moisture. In fact, those who did not meet IOM's guidelines had a lower intake of water through food moisture than those who did.

Montenegro-Bethancourt found that an increase in fruit and vegetables could lead to an increase in TWI (4). We have determined that this is inaccurate, as we have shown that food has little significance in TWI. Although there was a difference in amount of food moisture contributing to TWI between the two groups (522.6±694.4 vs. 416.3±202.9), they both contributed to the same percentage, 28%. The determining factor between the groups was fluid intake. However, analyzing children with a predominately natural foods diet (i.e. fruits and vegetables) could give us further understanding if food moisture could have a factor in the percentage of TWI coming from food moisture.

According to past studies, 83% of girls and 85% of boys do not meet IOM's Daily Reference Intake (DRI) values (2). This was higher than our estimated 60% of girls and 63% of boys. It was noted that boys were 1.76 times more likely to fail to meet guidelines than girls (1). The data conducted in this experiment confirm past literature. Up until the age of 9, both boys and girls have exactly the same TWI guidelines. However, once they enter the age group of 9-13, boys recommended TWI becomes higher than girls (2.4L vs 2.1L). This higher quantity recommended may make it difficult for boys to achieve adequate intake.

A cross sectional survey was conducted in Europe looking at the total fluid intake of children and adolescence. The European Food Safety Authority (EFSA) set the dietary reference intakes for individuals in Europe using slightly different measures than that of the USA's IOM reference intakes. Due to insufficient evidence regarding the TWI that would reduce the risk of chronic disease, IOM set adequate intakes based on the medium intake observed in national surveys preventing dehydration (14,2). EFSA developed their reference intake by observing intakes in populations with desirable urine osmolality, stating that this applies to individuals with moderate environments and physical activity level (14).

Though these guidelines differ slightly (IOM's guidelines recommend around .2 L more for each age group than EFSA), data showed that a majority of the European countries displayed similar trends in failing to meet EFSA's guidelines (15). This means that even though EFSE guidelines may be a little more manageable, there are still a high percentage of individuals failing to meet adequate intake. However, there were significant differences between countries and their adherence to the EFSA guidelines. Belgium displayed the highest non-adherence rate with > 90% of the children failing to meet the guidelines. Uruguay had the lowest percentage of non-adherence (<20%) (15). The data collected in this study (in Northwest Arkansas) concluded that 62% of children did not adhere to the guidelines. There are many factors that could contribute to the different mean TWI per area of data collected: climate, physical activity, access to clean water, and diet.

This present analysis has several strengths. We asked participants to make note in a food and liquid diary every time they consumed a beverage or a meal/snack. This is a better method than asking them to recall what they consumed at the end of the day. This could lead to underestimating values of liquid and food consumption as they may have forgotten (3). Also, using NDSR to evaluate the amount of water an individual consumes coming from food gives a more accurate analysis than doing it by hand.

However, there are also some limitations to the analysis. We ask the participants in this study to do food and liquid logs over a 48 hour weekend period. Children may be drinking and eating differently during a weekend than they typically do during a week of school. A weeklong study could improve the accuracy of the data by evaluating children in different settings. It would also be useful to have more than 81 participants at the time of analysis. Especially considering in the age group 1-3 we only had 2 boys and 2 girls. We could not accurately develop a conclusive statement regarding that age group.

In conclusion, even though the data indicated that water content of solid food contributed 28% of TWI, water from food was not different between the kids that met or did not met the dietary water guidelines. Also, higher plain water intake was associated stronger to total water intake than water from food. Our data might indicate the water from solid food is not a very strong determinant of appropriate water intake.

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