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Cody Shopper
University of Arkansas, Fayetteville

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Advisor: SA Kavouras
Committee Members: S.A. Kavouras, M. Ganio, E. Howie

Department of Health, Human Performance and Recreation: College of Education and Health Professions
University of Arkansas, Fayetteville, AR

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ABSTRACT

Introduction: Recent data from the National Health and Nutrition Examination Survey (NHANES) showed that more than 50% of children in the U.S. are hypohydrated. However, this assessment was based on a random single urine void which has several limitations in assessing hydration. Studies have shown that greater water consumption is associated with improved mood, cognition, increased physical activity and better overall nutrition. **Objective:** To assess water intake and hydration status in 3-13 year-old girls. **Methods:** 39 girls age 3-13 years-old (6.9 ± 2.9 y) collected their own urine samples for 24-hours on a Sunday. Subjects also recorded a food and fluid diary to track fluid and total water intake on Saturday and Sunday. The urine samples were analyzed for urine osmolality, urine specific gravity, color and volume. The food diaries were analyzed using NDSR software to calculate water intake. This study used the total water intake (TWI) values of children and girls age 3-13y from the Institute of Medicine (IOM) to separate subjects that met adequate intake values and those who failed. Dehydration was defined based on urine osmolality ≥ 800 mOsm/kg. **Results:** Thirty-eight percent of the girls were hypohydrated based on the urine biomarkers. Sixty percent of all girls did not meet the IOM recommendations for daily water intake. The ones that met the guidelines had lower 24-hr urine osmolality (774±232 vs. 619±223 mOsm/kg, P<0.05), consumed more plain water (1,145±744 vs. 366±171 mL/d, P<0.05), and had a higher TWI (2,558±605.4 vs. 1,150±250 mL/d, P<0.05) when compared to the ones who did not meet the guidelines. Higher water intake was also significantly associated with lower urine osmolality (R^2=0.125, P<0.01). **Conclusion:** The majority of girls 3-13y do not meet the dietary guideline for daily water intake and approximately 40% are hypohydrated. Lower water intake was associated with greater hypohydration in 3-13y old girls.

INTRODUCTION

Drinking water is an essential component of proper bodily function. Adequate hydration enables the body's physiological processes to operate efficiently. Health benefits associated with adequate hydration include increased metabolic function due to expanding cell volume, improved cognitive performance,[1] improved mood, reduction in type II diabetes and reduction in obesity.[2][6] However, hypohydration is a major public health concern. Urine osmolality is one measure that is used to determine the hydration status of an individual. It measures the number of dissolved particles per unit of water. Dehydration is defined by a urine osmolality value of 800 mOsm/kg or greater. One study examined NHANES data of children aged 4-13 years old and the prevalence of meeting adequate hydration recommendations from the IOM. It found that depending on gender and age group, less than 15-25% of kids met the recommendations of 1.7 L/day for children 4-8y, and 2.1 L/d for girls 9-13y.[4] Furthermore, additional research using NHANES data found that 54.5% of children aged 6-19y failed to meet adequate hydration recommendations.[4] There was also a disparity in the rate of dehydration among ages of children, race/ethnicity, and gender. Urine osmolality was higher in boys than in girls, higher in non-Hispanic blacks than non-Hispanic whites, and higher in 6-11y than 12-19y.[4]

According to U.S. Department of Education data, children attend public school, on average, for 6.6 hours for 180 days a year. With more than half of children in the U.S. not meeting adequate hydration recommendations,[7] ensuring access to drinking water at school is a promising solution. In 2010, federal legislature called The Healthy, Hunger-Free Kids Act of 2010 hoped to address this issue. It stated that every school is required to provide free drinking water in the same location as where meals are served by the 2011-12 school year. Federal policy attempts to treat children's hypohydration but the enactment has been unsatisfactory. In 59 middle and high schools studied in Massachusetts, less than half of the schools actually met these standards set by the federal legislature.[5]

In nearly all literature examining hydration status, only one spot urine sample is taken from an individual. The concentration of that one void is then analyzed and conclusions are made about the individual's level of hydration. Single spot urine concentration has an accuracy inferior to 24-hr collection of voids, like in the current study. This collection method leads to false positive/negatives due to how easily they are influenced by acute dietary intake, fluid, exercise and other factors.[11] For example, an individual's urine will be more concentrated after he/she exercises. Thus, if the sample is taken after intense physical exertion, then there is an increased risk of inaccurately characterizing their true hydration status. This will be one of the few studies to incorporate 24-hr urine collection for its sampling.

Due to timeliness, data collection was cut off at 39 parent and daughter pairs. By completion of the study, an expansive amount of data will be collected from 1,000 pairs of a parent (20-55y) and their child (3-13y) in Northwest Arkansas. Over one 24-hr period on the weekend, each void from the parent and child went into separate containers marked with the time. The urine samples were returned to the lab the following Monday. Next, the urine specific gravity, urine osmolality and urine color (1-8 scale) were recorded. In addition to void collection, the parent and child filled out food and fluid intake diaries on the Saturday and Sunday of testing. With this information, hydration and nutritional urine biomarkers were developed for girls aged 3-13y. We have hypothesized that children who meet the dietary guidelines of the IOM will be well hydrated, while the ones who do not meet the guidelines will not.

OBJECTIVES: To assess hydration biomarkers and water intake in girls age 3-13 years-old.

METHODS

Thirty-nine girls aged 3-13y were recruited into the study. Prior to participation, subjects and their parents met with a researcher to complete medical history and consent documents. Following the briefing, guidelines were provided with all necessary questionnaires. Urine containers were provided and instructions were given for the fluid and food diary. For collection, children were provided with 10 containers and one large container for the end of the day (if necessary). Containers for children were clearly differentiated by color or label. At completion of the study, each participant was financially compensated.

INCLUSION CRITERIA

Requirements for participation included; girls aged 3-13 years old, willing to collect urine samples and store them at room temperature and agree to avoid strenuous exercise on day of collection.

EXCLUSION CRITERIA

-Evidence of clinically relevant metabolic, cardiovascular, hematologic, hepatic, gastrointestinal, renal, pulmonary, endocrine or psychiatric history of disease, based on the medical history questionnaire

-Use of medication that interferes with water metabolism

-Surgical operation on digestive tract (e.g. bariatric surgery), except possible appendectomy

-Regular drug treatment within 15 days prior to start of the study

-Not willing to refrain from exercise on the day before and during urine collection

-Unwilling to collect urine

-Inability to participate in the entire study

-Use of diapers

-Enuresis or use of nappies during the day or during the night

SAMPLE ANALYSIS

The volume of each collected urine sample was measured and analyzed within 24-h for urine osmolality (UOsm), urine color (UC) and urine specific gravity (USG). Urine osmolality was measured in duplicate by freezing point depression (303 Advanced Osmometer, Advanced Instruments Inc, Norwood, MA, USA). Urine Specific Gravity was measured with a hand-held refractometer (ATAGO SUR-NE, Tokyo, Japan). Urine color was determined by comparing each specimen container next to an original eight-point urine color scale. The urine color evaluation was carried out by the same person at all times, standing in a well-lighted room (temperature 20-22°C) with samples placed on a clear glass tube against a white background.

DIETARY ANALYSIS

Dietary analysis was performed via NDSR software. All data outputs from NDSR were double checked by another scientist to ensure correct food entries. A type-I error of 0.05 or less would be the threshold for statistical significance.

STATISTICAL ANALYSIS

Data was analyzed for descriptive statistics (means, standard deviation, distribution) and associations were developed between water intake and hydration biomarkers via regression analysis. All data was analyzed by JMP statistical analysis software.

RESULTS

Using urine biomarkers, it was found that 38% of the girls were hypohydrated (Figure 1). When comparing the dehydrated vs. euhydrated (Figure 4), the euhydrated had higher TWI (1,865±929 vs. 1,584±692 mL/d, $P<0.05$) and plain water consumption (832±716 vs. 624±614 mL/d, $P<0.05$). There was a clear association with euhydrated subjects and higher water consumption. Moreover, this association was also seen with those who met IOM recommendations when comparing those who failed. Surprisingly, those who meet IOM recommendations drank more than three times the amount of plain water (1,144±744 vs. 366±171 mL/d, $P<0.05$) (Figure 3). Their TWI was also two times higher than those who did not meet IOM recommendations (2,558±705 vs. 1150±250 mL/d, $P<0.05$).

Table 1 General characteristics of participants categorized by age, weight, height and BMI

Total Subjects	Age	Weight (kg)	Height (cm)	BMI (kg/m^2)
39	6.9±2.9	28.8±15.9	122.2±20.7	18.2±4.9

Table 2 Dietary Reference Intakes from IOM based on age and gender

	IOM adequate intake values (mL)	IOM adequate intake values (oz)
Children 4-8 years old	1700 mL	57.5 oz
Girls 9-13 years old	2100 mL	71.0 oz

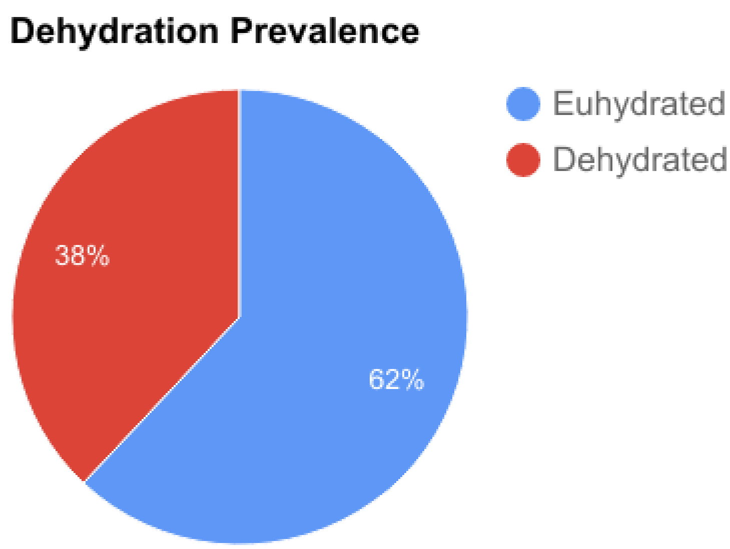

Fig. 1 Categorization of girls 3-13y by their 24-hr urine osmolality into hydration status

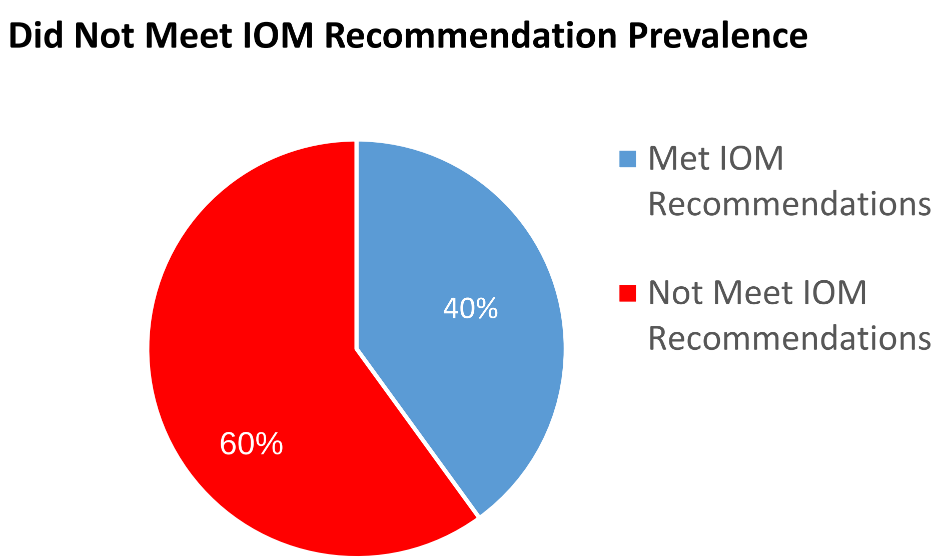

Fig. 2 Subjects grouped into those who met IOM recommendations for adequate intake and those who did not meet IOM recommendations

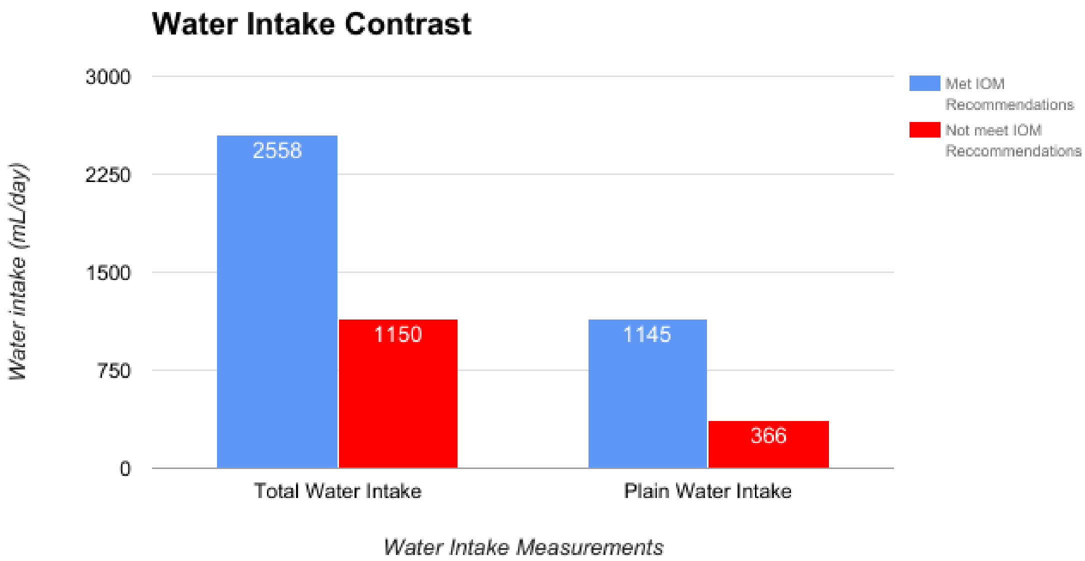

Fig. 3 Difference in water intake between those who met IOM recommendations and those who did not

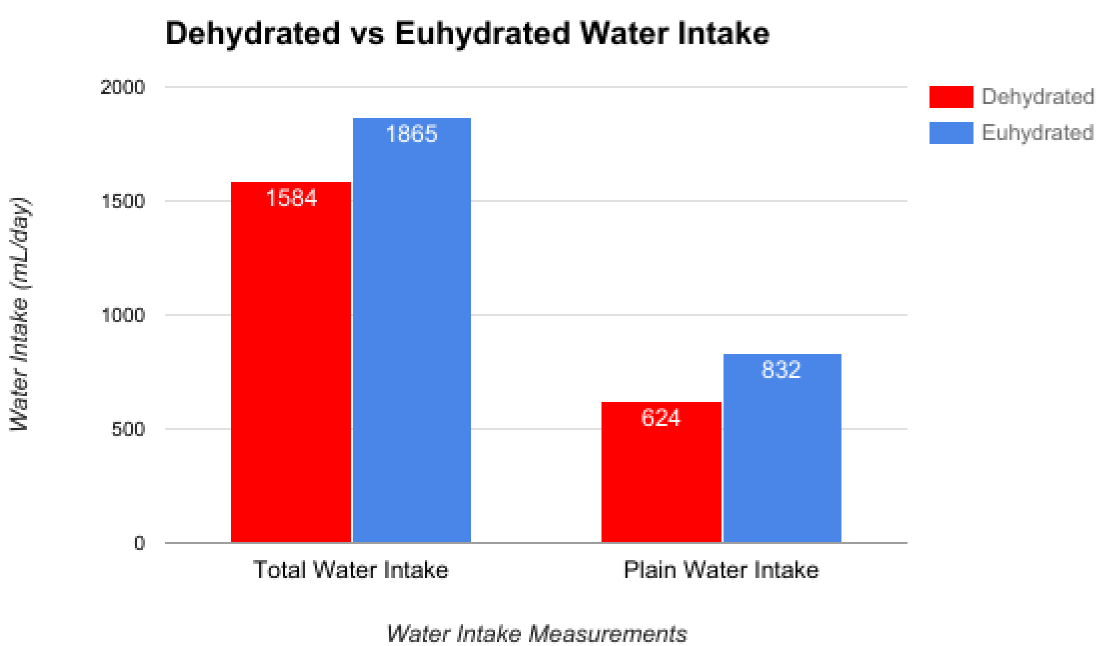

Fig. 4 Difference in water intake in euhydrated and dehydrated (≥800 mOsm/kg) individuals

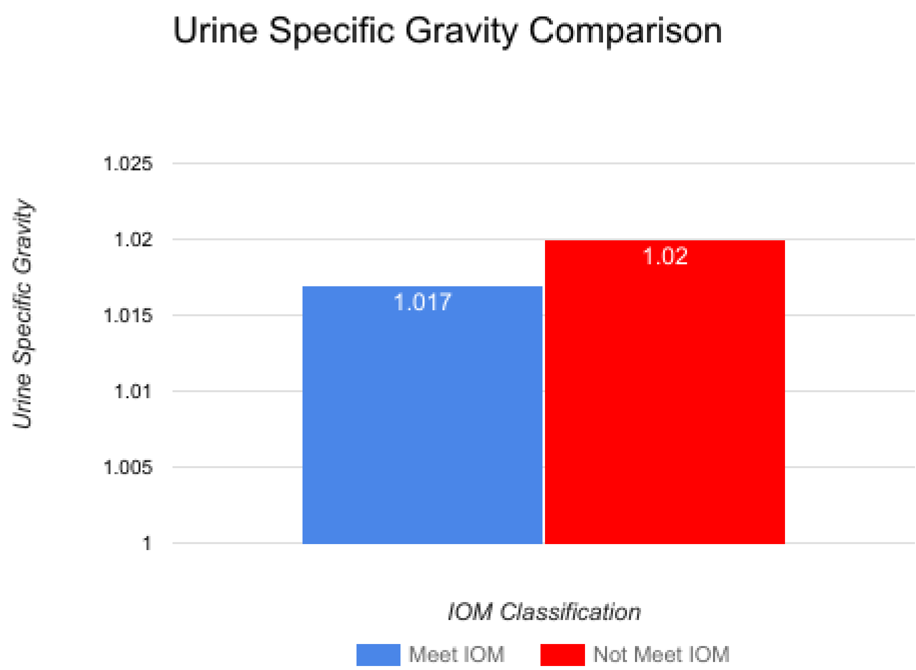

Fig. 5 Comparison of urine specific gravity based on those who met IOM recommendations for adequate intake and those who did not

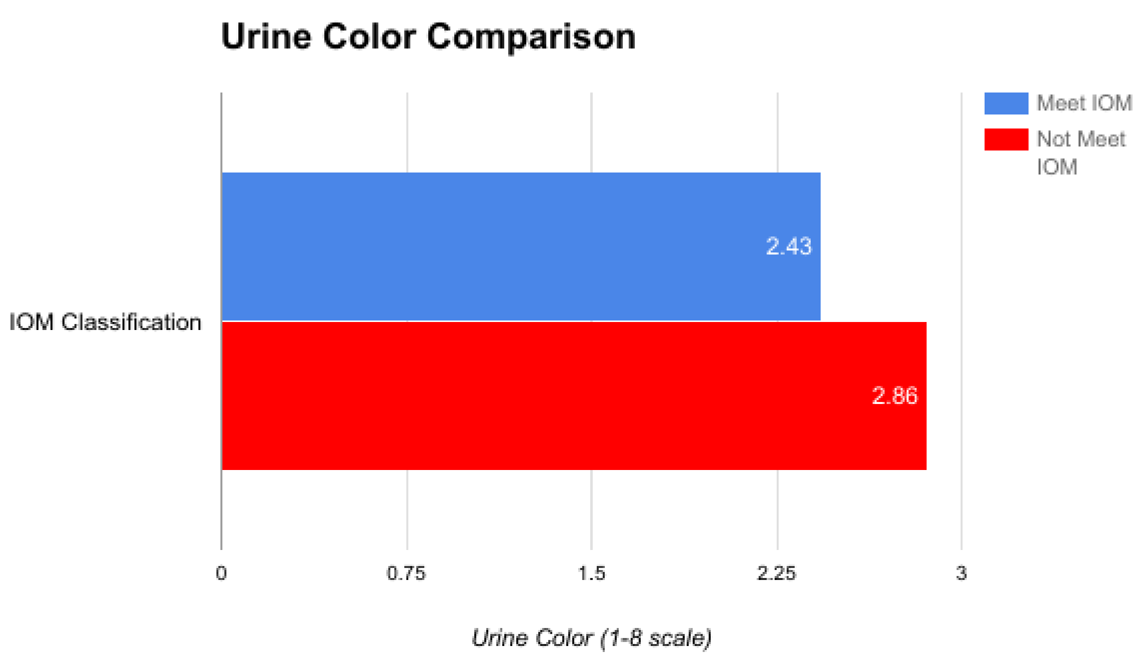

Fig. 6 Mean urine color of those who met IOM adequate intake recommendations and those who did not

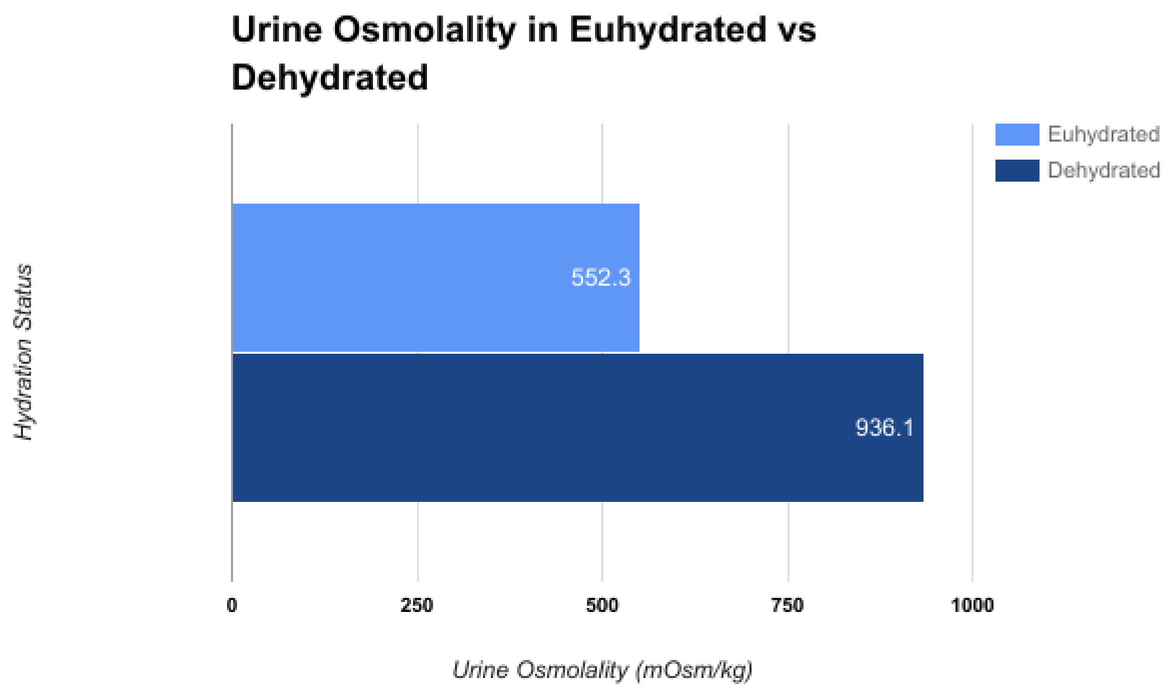

Fig. 7 Association of hydration status and urine osmolality values

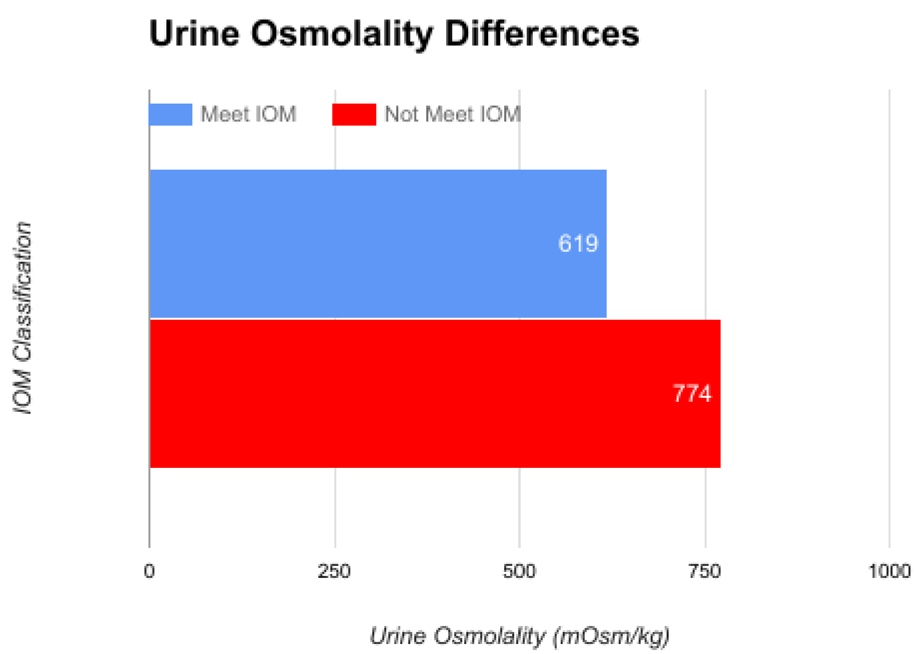

Fig. 8 Association of meeting IOM adequate intake recommendations and urine osmolality

DISCUSSION

An overwhelming factor contributing to U.S. children's hypohydration is the excessive intake of sugar-sweetened beverages (SSBs) in place of plain water. Adolescents, on average, consume upwards of 15% of their total calories from SSBs.[9] This does not bode well with the 2015-2020 Dietary Guidelines for Americans. It recommends a reduction of added sugar consumption to less than 10% of total calories per day.[8] This high consumption of SSBs is associated with a high risk of LDL cholesterol, hypertension and high triglycerides.[10] The over consumption of SSBs and under consumption of plain water cultivates future health risks at a young age.

It is a public health concern that 60% of girls in this study did not meet IOM water intake values. Given the health benefits listed (see page 3) and the increase in SSB consumption,[9] solutions are being developed to improve water intake in children. For example, New York City, NY installed a policy in 2009 to increase access to drinking water at lunchtime by installing water jets in the cafeteria. Additionally, this policy banned SSBs from vending machines. One study, in particular, examined the effect of increased access to drinking water and a ban on SSBs on children's BMI and the likelihood of them being overweight or obese. By the end of the study, they compiled data from over one million elementary and middle school students from New York City public schools. Since the policy change took place, the study concluded there was a reduction of 0.022 in girls' BMI and a 0.6% decreased likelihood of them being overweight or obese.[12] Installing water jets and decreasing access to SSBs promotes healthier lifestyles in an inexpensive fashion.

It is also worth discussing why our study yielded a much lower prevalence in dehydration than past studies. We expected to have a lower prevalence based on the design of the study. Our exclusion criteria included people who were unwilling to refrain from exercise the day of urine collection. Consequently, the subjects should yield less concentrated urine. However, performing 24-hr urine collection instead of single spot collection is what made the biggest difference. Since most literature examining hydration status only takes one sample from each participant, it is inherently influenced by their physical activity level immediately before the void, or if they consumed a SSB or bottle of water immediately before urination. All of these will fluctuate the urine osmolality of their one urine void. In one study using single spot collection in LA and NYC children, the single void was collected at the middle of the day during the week. At the time of collection, approximately 75% of the children did not drink water before leaving the house.[7] As a result, we saw that 63% of the LA samples and 66% of the NYC samples were dehydrated in this study. Their value is nearly twice as high as our findings of 38%.

In conclusion, the majority of 3-13y girls studied do not meet the dietary guidelines for daily water intake and approximately 40% are hypohydrated. Lower water intake was associated with greater hypohydration in 3-13y old girls.

LIMITATIONS

Given the timeliness of the study, we stopped data collection at 39 subjects. A sample size of this magnitude is too small to extrapolate large conclusions. Further, the data is not nationally representative because random sample methods were utilized. Also, the subjects were financially compensated for their time and efforts. Thereby, one may suggest that the study was comprised of participants from a disproportionate number of middle to lower socioeconomic status. It is possible the data could slant away from the true hydration status of all 3-13 year-old girls.

The biggest limitation with the study is centered on participants self-reporting their water intake and hydration habits. We have no verifiable method of ensuring the information they log is accurate. An individual may begin to drink more water or consume less beverages when they are suddenly cognizant of logging fluid intake. This is an unavoidable limitation that takes place in any nutritional study outside the eye of the research lab.

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