Relationship of sodium intake with obesity among Iranian children and adolescents

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Original Article

Abstract

BACKGROUND: Emerging evidence suggests a relationship between sodium (Na) intake and obesity risk. The aim of this study was to investigate the link between 24-hour (24-h) urinary Na excretion and adiposity measures in a sample of Iranian children and adolescents.

METHODS: This cross-sectional study was performed among 374 healthy individuals aged 11-18 years old. Random cluster sampling method was used to select the participants from 4 districts in Isfahan, Iran. Na excretion was estimated using a 24-h urinary sample. Creatinine (Cr) level was used to confirm the completeness of samples. Anthropometric measures including weight, height and waist circumference (WC) were obtained based on standard protocols.

RESULTS: The odds ratio (OR) for overweight/obesity in subjects with the highest tertile of Na excretion compared with the lowest tertile was 8.01 [95% confidence interval (CI) 4.20-15.3] in crude model and 8.33 (95% CI 4.14-16.8) after adjusting for potential confounders. The association was independent of intake of energy and sugar-sweetened beverages (SSBs). The OR for abdominal obesity in the highest tertile of Na excretion compared with the lowest tertile was 9.12 (95% CI 4.78- 17.4) in crude model and 9.75 (95% CI 4.88-19.5) after controlling for potential confounders. The association was independent of energy intake or SSBs consumption.

CONCLUSION: Our study showed a positive association between Na excretion and obesity among children and adolescents. Further investigation through longitudinal studies using a more representative sample of children and adolescents is suggested to determine whether this is a causal relationship.

Keywords: Sodium, Obesity, Children, Adolescents, Iran

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Introduction

Prevalence of overweight and obesity is rapidly increasing worldwide and it is projected that 57.8% of adults will be overweight or obese by year 2030.[1,2] Also, childhood obesity is now considered a major health problem both in developed and developing countries.[3,4] Iran, as a developing country, is also facing an increasing prevalence of obesity.[5] In 2012, a study estimated that the rate of obesity among 6 to 18 years old Iranian boys and girls was 10.2 and 13.6%, respectively. It is well established that pediatric obesity is associated with risk of many non-communicable diseases.[6] Therefore, it is important to identify major risk factors related to overweight and obesity in order to design and implement effective interventions.

Various reasons have been considered for the epidemic of obesity including dietary components.[7] Emerging studies suggest that dietary sodium (Na) may be a possible risk factor for obesity.[8] However, there are some controversies regarding the association between Na intake and obesity. It has been postulated that Na intake is accompanied by greater energy intake or increased consumption of energy-dense foods.[9] Also, there are evidences that Na intake is associated with higher weight, independent of calorie consumption.[10]

Na intake has increased in recent years mainly

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due to the higher consumption of processed foods, especially among children and adolescents.[11] Several studies have indicated that Na intake in Iranian adult population is also high and is about two times of the World Health Organization (WHO) recommendation.[12,13] A study among Iranian adults showed that the association between salt intake and blood pressure is related to adiposity measures.[14] However, few studies, with no study in Iran, have examined the effect of Na intake on overweight and obesity using 24-hour (24-h) urinary excretion, as the gold standard method, especially among children and adolescents. Thus, this study aimed to evaluate Na intake based on 24-h urinary Na excretion in relation to overweight/obesity in a sample of Iranian children and adolescents aged 11-18 years.

Materials and Methods

A cross-sectional study including children and adolescents aged 11 to 18 years living in Isfahan, Iran was carried out between September 2015 and February 2016. Sample size of 290 was estimated with the assumption of 80% power, and a 0.05 level of significance. Using random cluster sampling method, participants were recruited from 13 schools in 4 different districts. The main investigators then visited schools and invitations were sent to parents. Parents who agreed to study conditions were asked to complete an informed consent. Participants with acute or chronic diseases or on any medication or special diet were excluded. From 456 invited participants, 374 of them completed the study (response rate 82%). The study was approved by the Research and Ethics Committee of Isfahan University of Medical Sciences (IR. mui.rec.1394.3/294).

Twenty-four-hour urine collection containers were distributed among participants and parents, along with verbal and written instructions on how to complete the collection. It was emphasized that no change in dietary habits during the day of collection was allowed. The urine collection was completed over the weekends from Friday to Saturday during a 24-h period. Each participant was provided with a 2.5-litre polypropylene container used for the collection of 24-h urine sample. All participants were asked to initiate the collection by emptying their bladder, discarding first urine after getting up in the Friday morning, and continue the collection until next day morning. To help with urine collection, an additional 500 ml plastic cup was provided.

Measured parameters included 24-h urine volume, Na, and creatinine (Cr). Na was estimated using ion selective electrode method and urine Cr was measured by Jaffe reaction method.[15] Completeness of 24-h urine was defined by volume of collected urine $\geq$ 500 ml and 24-h Cr excretion $\geq$ 0.1 mg/kg body weight.[16]

Body weight was measured using a digital scale with minimal clothing and was recorded to the nearest 100 g. Height was estimated using an upstretched tape without shoes and was registered to the nearest 0.5 cm. Waist circumference (WC) was recorded halfway between the lowest rib and top of the hip bone to the nearest 0.5 cm. Body mass index (BMI) was calculated as weight in kg divided by height in m^2. Participants were grouped into weight categories (underweight, normal weight, overweight, obese) using the international obesity taskforce BMI reference cut-offs.[17] Abdominal obesity was defined as waist-to-height ratio (WHtR) of equal or more than 0.5.[6] Percent body fat (PBF) was measured using Omron BF511 body composition monitor (Omron Corp, Kyoto, Japan) and PBF > 25% for boys and > 35% for girls aged 11 years and older was defined as adiposity risk.[18]

A 168-item self-administered food frequency questionnaire (FFQ) was used to assess usual dietary intake. It consisted of a list of foods and a standard serving size for each.[19] The subjects were instructed to report the frequency of consumption of a given serving of each food item during the previous year on a daily, weekly or monthly basis. Portion sizes of consumed foods were converted to grams using household measures.[12] Dietary analysis was performed using Nutritionist IV software (First Databank, Hearst Corp, San Bruno, CA, USA).

Additional information regarding sociodemographic variables including age, sex and parents' education level, household income and past medical history were obtained using a self-administered questionnaire. The Physical Activity Questionnaire (PAQ), a self-administered, 7-day recall instrument with consistently high validity and moderate reliability[20] was used to assess the general levels of physical activity. The PAQ provides a summary of physical activity score derived from nine items, each scored on a 5-point scale. The mean score of these 9 items results in the final PAQ activity summary score. A score of 1 indicates low physical activity, a score of 2-4 indicates moderate physical activity and a score of 5 indicates high physical activity.

Descriptive statistics (mean values and standard deviations for continuous variables or numbers and percentages for categorical variables) were used to describe participant characteristics. One-way ANOVA and chi-square tests were used where appropriate. Multiple logistic regression models were used to assess the association between 24-h urinary Na excretion and (i) weight category and (ii) abdominal obesity. The unadjusted and adjusted models (age, sex, parents' education level, household income, physical activity) are presented. To assess whether the association between 24-h urinary Na excretion and adiposity outcome measures was independent of energy and sugar-sweetened beverages (SSBs) intake (including carbonated soft drinks, soda, squashes, fruit drinks), additional models were constructed with these covariates. To calculate the trend of odds ratios across increasing categories of tertiles of Na excretion, we considered the tertile categories as an ordinal variable in the logistic regression models. Analyses were completed using SPSS for Windows (version 18, SPSS Inc., Chicago, IL., USA), and a P-value < 0.05 was considered statistically significant.

Results

Table 1 shows the demographic characteristics of participants and data on urinary excretion and dietary intake across tertiles of Na excretion. Of 456 participants who started the 24-h urine collection, 50 samples were not returned. Also, some collections were excluded (n = 32) due to incompleteness of 24-h collection. Thus, 374 participants had complete and valid urinary samples and were included in the final analysis. Overall, 58.8% (n = 220) were girls and the mean age (standard deviation) was 14.4 (2.02) years. As can be seen, significant differences were found in terms of all presented variables across tertiles of Na excretion except for age and intake of SSBs. Cr excretion increased significantly across tertiles of Na excretion and significant correlation was observed between these variables (r = 0.62; P < 0.001). Number of girls was significantly more than boys across tertiles of Na excretion. Participants had mostly moderate physical activity level and there were no children and adolescents with high physical activity in our sample.

As table 2 shows, significant differences were observed regarding all the anthropometric measurements across tertiles of Na excretion. The mean BMI of the sample was 20.9 (4.16) kg/m² and 18.2% (n = 68) and 8.6% (n = 32) of the sample were overweight and obese, respectively.

Table 1. Baseline characteristics according to tertile of 24-h urinary sodium excretion among Iranian children and adolescents aged 11-18 years, Isfahan, Iran

Characteristics	Tertile of Na excretion (mg/d)			P*
	T1 < 1750	T2 1750-3420	T3 > 3420	
	Mean ± SD	Mean ± SD	Mean ± SD	
Participants (n)	128	129	117	
Age (year)	14.4 ± 2.02	14.3 ± 2.22	14.6 ± 2.09	0.720
Sex [n (%)]	128.0 ± 34.20	129.0 ± 34.50	117.0 ± 31.30	0.050
Boy	42.0 ± 27.30	57.0 ± 37.00	55.0 ± 35.70	
Girl	86.0 ± 39.10	72.0 ± 32.70	62.0 ± 28.20	
Na excretion (mg/d)	1230.0 ± 350.00	2540.0 ± 480.00	5860.0 ± 1810.00	< 0.001
Cr excretion (mmol/kg/d)	0.1 ± 0.03	0.1 ± 0.04	0.2 ± 0.09	< 0.001
Urine output (ml/d)	610.0 ± 140.00	870.0 ± 190.00	1320.0 ± 3.00	< 0.001
Energy intake (kcal/d)	1567.0 ± 252.00	1655.0 ± 258.00	1821.0 ± 338.00	< 0.001
SSBs** (g/d)	39.8 ± 33.10	40.9 ± 42.60	51.2 ± 48.30	0.070
Physical activity£ [n (%)]	128.0 ± 34.20	129.0 ± 34.50	117.0 ± 31.30	0.010
Low	42.0 ± 30.90	39.0 ± 28.70	55.0 ± 40.40	
Moderate	86.0 ± 31.60	90.0 ±37.80	62.0 ± 26.10	
High	None	None	None	

T: Tertile; SD: Standard deviation

* P-value (obtained from ANOVA for continuous variables and χ^2 test for categorical variables); ** Sugar-sweetened beverages included carbonated soft drinks, soda, squashes and fruit drinks; £ Physical activity was calculated using the physical activity questionnaire, score of 1 indicates low physical activity, score of 2-4 indicates moderate physical activity and score of 5 indicates high physical activity

Table 2. Anthropometric measurements according to tertile of 24-h urinary sodium excretion among Iranian children and adolescents aged 11-18 years, Isfahan, Iran

Variable	Total	Tertile of Na excretion (mg/d)			P*
		T1	T2	T3	
		< 1750	1750-3420	> 3420	
	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	
Weight (kg)	53.2 ± 14.20	48.4 ± 11.60	51.10 ± 12.20	60.90 ± 15.80	< 0.001
BMI (kg/m)	20.9 ± 4.16	19.3 ± 3.38	20.10 ± 3.28	23.50 ± 4.61	< 0.001
WHtR	0.5 ± 0.06	0.4 ± 0.05	0.46 ± 0.05	0.51 ± 0.07	< 0.001
PBF (%)	25.0 ± 6.65	22.4 ± 8.85	24.20 ± 9.59	28.70 ± 9.48	< 0.001
Underweight	30.0 ± 8.00	20.0 ± 16.10	5.00 ± 4.00	5.00 ± 4.00	< 0.001
Normal weight	244.0 ± 65.20	89.0 ± 71.80	101.00 ± 80.20	54.00 ± 43.50	
Overweight	68.0 ± 18.20	12.0 ± 9.70	20.00 ± 15.10	36.00 ± 29.80	
Obesity	32.0 ± 8.60	3.0 ± 2.40	1.00 ± 0.80	28.00 ± 22.60	
Abdominal obesity [n (%)]	93.0 ± 26.20	12.0 ± 3.40	25.00 ± 7.00	56.00 ± 15.80	< 0.001
Adiposity by PBF [n (%)]	93.0 ± 25.60	13.0 ± 3.60	25.00 ± 6.90	55.00 ± 15.10	< 0.001

T: Tertile; SD: Standard deviation; BMI: Body mass index; WHtR: Waist to height ratio; PBF: Percent body fat
* P-value (Obtained from ANOVA for continuous variables and χ^2 test for categorical variables)
Underweight was defined as BMI < 5th; normal weight was defined as 5th ≤ BMI < 85th; overweight was defined as 85th ≤ BMI < 95th; obesity was defined as BMI ≥ 95th; abdominal obesity was defined as WHtR ≥ 0.05; adiposity was defined as PBF > 25% for boys and > 35% for girls

In total, 26.7% (n = 111) of participants were classified as centrally obese. Based on PBF as another marker of adiposity, 25.6% (n = 93) of participants had excess body fat.

Odds ratios (OR) for weight category (overweight/obesity) and abdominal obesity across tertiles of Na excretion are provided in tables 3 and 4. The OR for overweight/obesity in subjects with the highest tertile of Na excretion compared with the lowest tertile was 8.01 [95% confidence interval (CI) 4.20-15.6] in crude model and 8.33 (95% CI 4.14-16.8) after adjusting for potential confounding variables. The association remained significant after adjusting for intake of energy and SSBs. The OR for abdominal obesity in the highest tertile of Na excretion compared with the lowest tertile was 9.12 (95% CI 4.78-17.4) in crude model and 9.75 (95% CI 4.88-19.5) after controlling for potential confounders. The association was independent of energy intake or SSBs consumption.

Discussion

This study was the first to assess the relationship between 24-h urinary Na excretion and adiposity in a sample of Iranian children and adolescents. Among schoolchildren and adolescents aged 11- 18 years, we found significant associations between 24-h urinary Na excretion and overweight/obesity and abdominal obesity, independent of intake of energy and SSBs.

Table 3. Odds ratios (OR) for overweight and obesity according to tertile of 24-h sodium excretion among Iranian children and adolescents aged 11-18 years, Isfahan, Iran

Variable	Tertile of Na excretion (mg/d)			P for trend
	T1	T2	T3	
	< 1750	1750- 3420	> 3420	
		OR (95%CI)	OR (95%CI)	
Crude 1	1	1.37 (0.67-2.82)	8.01 (4.20-15.3)	P < 0.001
Model 1	1	1.36 (0.65-2.84)	8.70 (4.44-17.0)	P < 0.001
Model 2	1	1.47 (0.69-3.14)	8.33 (4.14-16.8)	P < 0.001
Model 3	1	1.43 (0.67-3.08)	7.80 (3.86-15.8)	P < 0.001
Model 4	1	1.12 (0.50-2.51)	4.97 (2.34-10.6)	P < 0.010

Overweight/obesity defined as BMI ≥ 85th
T: Tertile; OR: Odds ratio; CI: Confidence interval; Reference category: Low/normal body mass index vs overweight/obesity; Crude: Unadjusted
Model 1: Adjusted for age, sex, parents' education level and household income; Model 2: Additionally, adjusted for physical activity (low, moderate, high); Model 3: Additionally, adjusted for sugar-sweetened beverages (g/d); Model 4: Additionally, adjusted for energy intake (kcal/d)

Table 4. Odds ratios (OR) for abdominal obesity according to tertile of 24-h sodium excretion among Iranian children and adolescents aged 11-18 years, Isfahan, Iran

Variable	Tertile of Na excretion (mg/d)			P for trend
	T1 < 1750	T2 1750-3420	T3 > 3420	
		OR (95%CI)	OR (95% CI)	
Crude	1	1.98 (0.10-3.94)	9.12 (4.78-17.4)	P < 0.001
Model 1	1	2.12 (1.06-4.24)	10.0 (5.13-19.5)	P < 0.001
Model 2	1	2.33 (1.13-4.78)	9.75 (4.88-19.5)	P < 0.001
Model 3	1	2.30 (1.11-4.75)	9.19 (4.58-18.4)	P < 0.001
Model 4	1	2.00 (0.96-4.20)	6.65 (3.24-13.7)	P < 0.010

Abdominal obesity defined as WHtR > 0.5 cm

T: Tertile; OR: Odds ratio; CI: Confidence interval; Crude: Unadjusted; WHtR: Waist to height ratio

Model 1: Adjusted for age, sex, parents' education level, household income; Model 2: Additionally, adjusted for physical activity (low, moderate, high); Model 3: Additionally, adjusted for sugar-sweetened beverages (g/d); Model 4: Additionally, adjusted for energy intake (kcal/d)

Our findings are consistent with previous studies performed in children and adolescents. For example, in a sample of Australian children aged 4-12 years, with an additional 17 mmol/d of Na, the risk of being overweight/obese or abdominally obese increased 23% and 15%, respectively.[21] They revealed that potential adipogenic effect of Na relates to total body weight and is not specific to central fat distribution. Similarly in a longitudinal study among German children and adolescents aged 3-18 years, positive association between Na intake and BMI z score was reported.[22] However, there was limited evidence for a temporal relationship. In contrast, among Canadian schoolchildren, no difference in Na intake was found, assessed by a web-based 24-h recall, across weight categories.[23] Differences in methodologies may explain the results.

Several possible mechanisms could explain the observed association between Na excretion and obesity. First, as Na excretion was correlated to energy intake in our study, it is possible that Na intake is associated with obesity through increased energy intake or intake of energy-dense SSBs. However, we found that the association between Na excretion and weight category was independent of energy or consumption of SSBs, suggesting that other pathways are involved. Another mechanism suggested by previous studies is that higher Na intake is accompanied by increased formation of adipocyte tissue which could be through altering fat metabolism in the body. In rats, those fed a high-Na diet, compared with those fed a normal-Na diet, had a greater increase in adipocyte mass despite the same amount of overall food consumed. In addition, rats fed the high-Na diet displayed greater uptake of glucose and conversion into lipids within adipocyte tissue.[7,24] More studies are needed to confirm these effects in humans.

First limitation of the present study is the cross-sectional design which keeps us from drawing a causal relationship between study parameters. Also, the sample may not be representative of Iranian population. Therefore, caution is warranted when interpreting the results. Furthermore, urine samples were collected through weekends which may not show the usual intake of Na since school day collections were not allowed by school administrators. However, participants were instructed not to alter their dietary routines during the day of urine collection. The main strength of this study is the use of 24-h urinary samples which is considered as the gold standard method for assessing Na intake. Also, our study is among few efforts to estimate the association between Na excretion and obesity in a relatively large sample of children and adolescents around the world.

Conclusion

In conclusion, our study showed a positive association between 24-h Na excretion and obesity among children and adolescents. Therefore, Na and salt reduction strategies could be important part of the programs aimed at reducing the burden of overweight/obesity. Future studies with prospective designs are warranted along with efforts to determine the exact mechanism of the effect of Na on overweight/obesity risk.

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Conflict of Interests

Authors have no conflict of interests.

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