Is urinary sodium excretion related to anthropometric indicators of adiposity in adults?

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Background: Although increasing salt intake is associated with greater odds of obesity, little is known about its relationship with body fat. We investigated the relation of urinary sodium (UNa) with obesity indices, including Clínica Universidad de Navarra–Body Adiposity Estimator (CUN-BAE), a body shape index (ABSI), body mass index (BMI), waist circumference (WC), and waist-to-height ratio (WHtR). **Materials and Methods:** A total of 508 free-living adults aged ≥ 19 years were selected through stratified multistage random method as a representative of general population from central parts of Iran and were included in this cross-sectional study. Dietary sodium intake was measured using 24-h UNa (24-UNa) excretion. Weight, height, and WC were measured using standard protocols and calibrated equipment and used to measure obesity indicators, including BMI, WHtR, ABSI, and CUN-BAE. Adjusted univariate multiple logistic regression was used to assess the risk of having greater obesity measures across the tertiles of 24-UNa. **Results:** Individuals in the top tertile of 24-UNa in comparison with those in the first tertile had greater body weight (72.02 ± 1.00 vs. 66.02 ± 0.89 kg; $P < 0.0001$), BMI (26.14 ± 0.33 vs. 24.82 ± 0.29 kg/m^2; $P = 0.007$), and CUN-BAE (29.89 ± 0.42 vs. 28.38 ± 0.78; $P = 0.036$). There was a trend toward an increment in WC by increasing sodium intake ($P = 0.073$). After controlling for potential confounders, individuals with greater sodium consumption had greater chance for overweight (odds ratio [OR]: 1.004, 95% confidence interval [CI]: 1.001–1.007; $P = 0.015$), abdominal obesity (OR: 1.004, 95% CI: 1.00–1.008; $P = 0.031$), and more body fat (OR: 1.007, 95% CI: 1.003–1.01; $P = 0.001$). No significant association was found for sodium and WHtR and ABSI. **Conclusion:** Greater 24-UNa excretion was associated with greater means of body weight, BMI, WC, and CUN-BAE. Although changes in obesity indices per each additional 24-UNa excretion were small, our findings are relevant because of the rising obesity epidemic.

Key words: Abdominal obesity, body fat, obesity, salt, sodium

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INTRODUCTION

More than half of Iranian adults are overweight or obese,[1] and their salt consumption is estimated to be more than two times the World Health Organization recommendation.[2] In the last years, several lines of evidence have revealed a direct link between salt intake and risk of obesity in American and UK population even after adjustment for energy intake.[3-7] However, these studies have some critical limitations which warrant further research. For example, most of the previous studies have estimated salt intake using unreliable tools, such as food records or food frequency questionnaire (FFQ), whereas the most precise method is measuring 24-h urinary sodium (24-UNa) excretion.[8] In addition, obesity has been generally determined using body mass index (BMI) or waist circumference (WC).[9] Although these measures are widely used in clinical practice, they have their own limitations.[10] Some other adiposity indices have been developed to remove the limitations of BMI and WC, which mainly are indicators of body shape rather than body weight. Among these adiposity indicators, waist-to-height

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ratio (WHtR) as a better index of abdominal obesity than WC,[11] a body shape index (ABSI) as an index of trunk fat,[12] and Clínica Universidad de Navarra–Body Adiposity Estimator (CUN-BAE) as an index of body fat[13] have been further the main focus of several epidemiological studies in relation to different chronic diseases.

Although the association between salt and body weight or BMI has been explored by various studies, the association of salt with body shape indicators has poorly been examined and there are only a few studies that assessed the relationship between sodium intake and body fat.[14,15] A cross-sectional study among Korean children[15] and a multiethnic cohort[14] found a direct link between sodium and body fat, which is determined by dual-energy X-ray absorptiometry (DEXA). Furthermore, a recent large cross-sectional study among adults in Japan, China, United Kingdom, and United States suggested that the magnitude of association between salt and BMI in different populations may vary.[16]

To the best of our knowledge, there is no published dataset among either Iranian or any of the Middle Eastern populations on plausible association of salt with obesity indices. Nevertheless, in an earlier analysis among Iranians, we showed that the association between salt intake and hypertension might be mediated through the association between salt intake and body weight and WC,[17] which may suggest a positive link between salt and anthropometric measures among Iranians. Given the high prevalence and rising epidemic of obesity as well as high salt consumption in the Iranian population, we aimed to investigate the relationship between salt intake and different indices of obesity, body fat, and shape in Iranian adults.

MATERIALS AND METHODS

Design and subjects

This cross-sectional study was conducted on data collected in 2007 of the Isfahan Healthy Heart Program (IHHP)[18] from the last phase of Isfahan Healthy Heart Program. IHHP is a comprehensive integrated community-based trial aiming to improve cardiovascular behavior and reduce cardiovascular risks in the whole population and was conducted by Isfahan Cardiovascular Research Center (ICRC) (a WHO collaborating center).[19,20] Sampling was carried out by stratified multistage random method as a representative of general population from central parts of Iran, including Isfahan, Najafabad, and Arak districts, based on population distribution reported by the national population census in 2000.[19,20] In a major final cross-sectional survey, a total of 9660 adults aged ≥19 years were selected randomly, based on their gender, age, and settlement distributions in each community. Detailed information regarding the methods of this program has been described elsewhere.[20,21] The 24-h urine collection was done in subsample of 806 participants in Isfahan city. Only people with Iranian nationality were enrolled in the study. Subjects were excluded if they met at least one of the following criteria: 1) having liver, kidney or blood disorders, mental retards, hypertension, bleeding disorders, type 2 diabetes, diabetes insipidous 2) being pregnant, 3) consuming diuretic medicines, 4) being in the menstrual period at the time of the study, 5) having less than 500 mL urine/ day, 6) reporting more than one missed voiding or 24Hurine Cr (24HUCr) <20 mg/dL/kg in males and <15 mg/mL/kg in female aged < 50 years and 24HUCr <10 mg/dL/kg in males and <7.5 mg/mL/kg in females aged ≥50 years. Finally, 508 participants who had valid measures for anthropometric measures, including weight, height, and waist circumference, as well as complete 24HU collection were included in the present analysis. The present study was approved by the Ethical Committee of ICRC.

Data collection

Sociodemographic status was assessed using a standard questionnaire completed by trained health interviewers at home. 24-h urinary specimen was collected according to the INTERnational study of SALT and blood pressure protocol.[21]

Smoking status was categorized as smoker, ex-smoker, and nonsmoker.[22] Those who had smoked 100 cigarettes through their lifetime and currently smoked were considered as smokers, those who smoked at least 100 cigarettes in their lifetime but had quit smoking at the time of interview were defined as ex-smokers, and others as nonsmokers. Physical activity was assessed by means of a validated physical activity questionnaire.[23] This questionnaire was divided into four main domains according to the Iranians' lifestyle (leisure time, occupational, household, and transportation physical activities).

We assessed dietary intake by the use of a validated block-format, 48-item FFQ.[24] Participants reported their frequency consumption of the food items over the last preceding year on a daily, weekly, or monthly basis in an open-ended format.[25] Participants were also requested to choose the "never/seldom" response if they never or rarely consumed a given food item. Seldom and never were calculated as "zero." Finally, we converted the reported frequency of each food item to weekly consumption. Trained interviewers completed the FFQs in the face-to-face manner.

The global dietary index (GDI) was also defined as a measure of diet quality.[26] To calculate GDI, 31 questions regarding the frequency of consumption of different food items were categorized into seven questions, including (1) fast foods (n = 4), (2) vegetables (n = 7), (3) beans, chicken, soya protein, or fish (n = 4), (4) sweets (n = 6), (5) hydrogenated oil, ghee, animal fats, or butter (n = 4), (6) meat, egg, or whole dairy products (n = 4), and (7) nonhydrogenated oil and olive oil (n = 2). Each question was given a score ranged from 0 to 2 according to the frequency of food consumption. Total score was estimated by summing the responses to all seven questions. Smaller scores indicated better dietary behaviors.

Urine collection

All participants were educated how to collect urinary specimen. In order that, a clinic staff explained the accurate method of collecting urinary specimen orally and provided a written instruction for each participant. Participants were provided a sterile plastic container for 24-h urine collection labeled with the participants' name and a special code. They were asked to collect urine sample from 7 am to 7 am the next day after excluding the first sample of the 1st day and containing the first urine of the 2nd day. If a person was unable to deliver urine samples for any reason, samples were collected from their home.

For those who were not capable to deliver the urinary specimens to the health centers, data were collected by interviewers at home. The urinary chemical parameters including Na and Cr were measured in 24-h urine samples. To assess the accuracy of urinary samples as 24-h specimens, we measured the concentration of Cr using Jaffe method (Technical SMA 12–60). To avoid underestimating dietary sodium intake, the content of UNa was identified using the flame photometry technique.[27]

Anthropometric assessments

Weight was measured using a balance scale while participants were minimally clothed without shoes and recorded to the nearest 100 g. Height was determined using a wall-fixed meter in standing position, without shoes and normal state of shoulders and recorded to the nearest 0.5 cm. BMI was calculated as dividing body weight (kg) by the square of height (m^2). Waist circumference (WC) was measured according to the WHO protocol at the midway between the lowest rib margin and the iliac crest at the midaxillary line using an unstretched tape without any pressure to body surface[28] and recorded to the nearest 0.1 cm. ABSI was calculated based on a previously suggested formula by Krakauer and Krakauer.[12] CUN-BAE was calculated by considering participants' age, sex, and BMI based on the suggested formula.[13]

Definition of terms

Overweight/obese was considered as BMI ≥25 kg/m^2.[29] Abdominal obesity was defined as WC more than 88 cm in women and more than 102 cm in men.[30] Moreover, we defined abdominal obesity as having WHtR >0.5.[31] The median cut points of ABSI and CUN-BAE were considered to categorize individuals into two groups as having greater trunk or body fat (more than median) and less fat (lower than median).

Statistical analysis

General characteristics of participants were reported as means (standard error [SE]) or count (%). Categorical variables were compared using the Chi-square test and quantitative variables using analysis of variance or Kruskal–Wallis Test (if the assumptions were not held) across the tertiles of 24-UNa. Both univariate multiple logistic regression and linear regression were used to explore the association between anthropometric measures and 24-UNa in crude and adjusted models. In model 1, we adjusted for age and sex. Further statistical control was performed for sleep duration, smoking status, tertile of total daily physical activity, education level (category), and occupation in model 2. Model 3 was additionally adjusted for GDI. We also calculated odds of having greater anthropometric measures per one-unit increment in 24-UNa in crude and multiple-adjusted models, applying the above-mentioned models. For all statistical analyses, we used the Statistical Package for the Social Sciences (SPSS version 15, SPSS, Inc., Chicago, IL, USA). $P <$ 0.05 was considered significant in all statistical analyses.

RESULTS

A total of 508 healthy individuals, who had valid 24-h urinary collections, were included in the statistical analysis. The mean 24-h UNa was 164.58 ± 2.95 (SE) mEq/day, and it was higher in men than women (175.45 ± 4.84 vs. 156.41 ± 3.59 mEq/day; P = 0.001). Basic demographic characteristics of the study population across the tertiles of 24-h UNa are shown in Table 1. Compared with participants in the first tertile, those who were in the third tertile tended to be men (P = 0.002) and physically active (P = 0.031), less university educated (P = 0.008), having more manually jobs (P = 0.003), and have higher prevalence of overweight or obesity (60.0 vs. 50.3%; P = 0.025). The prevalence of abdominal obesity, being current smoker, mean sleep duration, and age did not differ significantly across the tertiles of 24-UNa.

The weekly frequency of food items across the tertiles of 24-UNa is presented in Table 2. Participants in the highest tertile in comparison with those in the first tertile had lower intake of confections (1.74 ± 0.22 vs. 2.72 ± 030; P = 0.004). No significant differences were observed regarding the consumption of sugar-sweetened beverage, fast food, refined grains, oils, and GDI.

The mean (SE) anthropometric measures according to UNa excretion tertiles are reported in Table 3. In the whole population, individuals in the highest tertile versus those in the first had greater body weight (72.02 ± 1.00 vs. 66.02 ± 0.89 kg; P < 0.0001), BMI (26.14 ± 0.33 vs.

Table 1: General characteristics of participants across tertiles of 24-h urinary sodium excretion

Variables	UNa excretion			
	Tertile 1 (*n*=167)	Tertile 2 (*n*=171)	Tertile 3 (*n*=170)	*P*[a]
Age (years)[b]	39.17±1.10	36.02±0.95	37.37±0.95	0.084
Physical activity level (MET-min/week)[b]	662.58±36.59	801.11±50.10	803.20±40.95	0.008
Leisure time physical activity (MET-min/week)[b]	137.48±16.06	163.56±16.91	110.93±12.19	0.090
Work site physical activity (MET-min/week)[b]	167.41±29.38	310.99±45.40	337.06±43.66	0.001
Homework physical activity (MET-min/week)[b]	301.40±23.47	275.66±28.57	310.06±27.38	0.354
Transfer physical activity (MET-min/week)[b]	56.29±10.06	50.90±7.36	51.36±4.54	0.519
Sleep duration (hour/day)[b]	7.83±0.12	7.84±0.14	7.72±0.13	0.76
Male, *n* (%)	53 (31.7)	84 (49.1)	81 (47.6)	0.002
Overweight or obese, *n* (%)[c]	84 (50.3)	78 (45.6)	102 (60.0)	0.025
Abdominal obese, *n* (%)[c]	67 (40.1)	60 (35.1)	61 (35.9)	0.59
Educational level (years), *n* (%)				
0-5	42 (25.1)	35 (20.5)	46 (27.1)	0.018
6-12	51 (48.5)	86 (50.3)	99 (58.2)	
≥13	44 (26.3)	50 (29.2)	25 (14.7)	
Occupational category, *n* (%)				
Homemaker	86 (51.5)	66 (39.1)	79 (46.5)	0.003
Manual	19 (11.4)	29 (17.2)	25 (14.7)	
Nonmanual	27 (27)	39 (23.1)	50 (29.4)	
Retired, unemployed, student	35 (21.0)	35 (20.7)	16 (9.4)	
Current smokers, *n* (%)	16 (9.6)	20 (11.8)	14 (8.5)	0.138
UNa excretion (total) (mEq/d)	96.65±1.89	156.31±1.26	239.63±3.50	<0.0001
UNa excretion in men (mEq/d)	91.60±3.79	158.01±1.68	248.39±5.82	<0.0001
UNa excretion in women (mEq/d)	99.00±2.11	154.67±1.86	231.66±3.92	<0.0001

Cutoff values for tertiles of UNa excretion (mEq/d) are as follows=<129.0, 129–184, 184≤. [a]Derived from one-way ANOVA and Chi-square test for continuous and categorical variables, respectively; [b]Values are means±SEs; [c]Overweight was defined as a BMI ≥25 kg/m^2. Central obesity was defined as a waist circumference ≥88 cm in women and a waist circumference ≥102 cm in men. ANOVA=Analysis of variance; SEs=Standard errors; UNa=Urinary sodium; BMI=Body mass index; MET=Metabolic equivalent of task

Table 2: Dietary intakes of participants across the tertiles of 24-h urinary sodium excretion[a]

Food items (frequency/week)	UNa excretion			
	Tertile 1 (*n*=167)	Tertile 2 (*n*=171)	Tertile 3 (*n*=170)	*P*[b]
All (*n*=508)				
Sugar sweetened beverages	1.37±0.20	1.25±0.14	1.33±0.20	0.36
Fast food	0.54±0.06	0.75±0.08	0.59±0.08	0.11
Nonhydrogenated vegetable oil	6.72±0.31	6.44±0.32	6.55±0.34	0.53
Hydrogenated vegetable oil	3.02±0.33	3.27±0.33	3.90±0.35	0.09
Sweets	2.72±0.30	2.50±0.25	1.74±0.22	0.004
Refined grains	15.86±0.45	16.16±0.47	16.80±0.48	0.30
Fruits and vegetables	16.59±0.67	16.95±0.73	16.80±0.67	0.99
Global dietary index	0.73±0.02	0.79±0.02	0.77±0.02	0.18

Cutoff values for tertiles of UNa excretion (mEq/d) are as follows=<129.0, 129-184, 184≤. [a]Values are mean±SE; [b]From analysis of variance (ANOVA) or Kruskal–Wallis test. ANOVA=Analysis of variance; SE=Standard error; UNa=Urinary sodium

24.82 ± 0.29 kg/m^2; P = 0.007), and CUN-BAE (29.89 ± 0.42 vs. 28.38 ± 0.78; P = 0.036). There was a trend toward an increment in WC by increasing sodium intake (P = 0.073). No significant differences were observed in WHtR means across the tertiles of UNa excretion (P = 0.221), but ABSI means decreased significantly (P = 0.023). A positive correlation between 24-UNa and BMI and WC, but a negative correlation for ABSI, was also observed in the whole population. In the stratified analysis by sex, males with higher UNa excretion had greater weight, BMI, WC, WHtR, and CUN-BAE. In women, no significant difference in any anthropometric measures was found.

Table 4 shows the odds of having anthropometric measures greater than median, overweight or obesity, and abdominal adiposity by the tertiles of UNa excretion as well as considering it as a continuous variable. Although the risk of overweight or obesity was 48% greater in individuals in the third tertile (95% confidence interval: 0.96–2.28; P = 0.026), further adjustment for potential confounders eliminated the significance (odds ratio = 1.59; 95% CI: 0.97–2.59; P = 0.142). There were not any more significant associations between 24-UNa and other anthropometric measurements. However, when 24-UNa was considered as a continuous variable in analysis, it was slightly but significantly associated

Table 3: Mean (standard error) anthropometric measures according to urinary sodium excretion

Variables	UNa excretion			P^a	r^b
	Tertile 1 (*n*=167)	Tertile 2 (*n*=171)	Tertile 3 (*n*=170)		
All (*n*=508)					
BMI (kg/m²)	24.82±0.29	24.99±0.34	26.14±0.33	0.007	0.174*
WC (cm)	88.78±0.86	88.36±0.90	91.05±0.92	0.073	0.121*
WHtR	0.55±0.006	0.54±0.006	0.55±0.006	0.221	0.046
CUN-BAE	28.38±0.78	30.52±0.69	29.89±0.42	0.036	0.011
ABSI	0.082±0.0004	0.081±0.0004	0.081±0.0002	0.023	−0.120*
Male (*n*=218)					
BMI (kg/m²)	24.38±0.45	24.15±0.45	26.12±0.43	0.003	0.211*
WC (cm)	88.60±1.35	88.20±1.23	93.30±1.15	0.009	0.185*
WHtR	0.52±0.009	0.51±0.007	0.54±0.007	0.023	0.155*
CUN-BAE	22.04±0.77	20.96±0.78	24.39±0.70	0.004	0.179*
ABSI	0.080±0.0007	0.080±0.0004	0.080±0.0004	0.750	−0.008
Female (*n*=290)					
BMI (kg/m²)	25.03±0.37	25.79±0.50	26.17±0.49	0.235	0.126**
WC (cm)	88.86±1.09	88.52±1.32	89.00±1.38	0.938	0.006
WHtR	0.56±0.007	0.56±0.009	0.56±0.009	0.986	−0.006
CUN-BAE	34.87±0.65	35.55±0.78	36.10±0.78	0.564	0.180
ABSI	0.083±0.0005	0.081±0.0007	0.080±0.0006	0.010	−0.193

Cutoff values for tertiles of UNa excretion (mEq/d) are as follows=<129.0, 129–184, 184≤. [a]Derived from one-way ANOVA or Kruskal–Wallis test; [b]Correlation between anthropometric measures and 24-UNa excretion; *Correlation is significant at the 0.01 level (two-tailed); **Correlation is significant at the 0.05 level (two-tailed). ANOVA=Analysis of variance; BMI=Body mass index; 24-UNa=24-h urinary sodium; WC=Waist circumference; WHtR=Waist-to-height ratio; CUN-BAE=Clínica Universidad de Navarra–Body Adiposity Estimator; ABSI=A body shape index

Table 4: Adjusted odds ratio (95% confidence interval) for obesity, abdominal obesity and greater body fat according to tertiles of urinary sodium excretion

Variables	24-UNa			P^a	Continuous	P^b
	Tertile 1	Tertile 2	Tertile 3			
BMI ≥25 kg/m²						
Crude model	1 (reference)	0.83 (0.54-1.27)	1.48 (0.96-2.28)	0.026	1.003 (1.001-1.006)	0.017
Model 1	1 (reference)	1.03 (0.65-1.64)	1.82 (1.14-2.90)	0.016	1.005 (1.002-1.008)	0.001
Model 2	1 (reference)	1.05 (0.65-1.70)	1.56 (0.96-2.54)	0.148	1.004 (1.001-1.007)	0.014
Model 3	1 (reference)	1.08 (0.67-1.75)	1.59 (0.97-2.59)	0.142	1.004 (1.001-1.007)	0.015
WC ≥88 cm in women and 102 in men						
Crude model	1 (reference)	0.81 (0.52-1.25)	0.83 (0.54-1.30)	0.590	1.00 (0.997-1.003)	0.977
Model 1	1 (reference)	1.39 (0.82-2.37)	1.33 (0.79-2.26)	0.417	1.004 (1.001-1.008)	0.015
Model 2	1 (reference)	1.43 (0.83-2.49)	1.26 (0.73-2.19)	0.429	1.004 (1.00-1.008)	0.030
Model 3	1 (reference)	1.46 (0.84-2.54)	1.28 (0.74-2.23)	0.396	1.004 (1.00-1.008)	0.031
WHtR ≥0.5						
Crude model	1 (reference)	0.71 (0.45-1.12)	1.09 (0.68-1.74)	0.151	1.001 (0.998-1.004)	0.435
Model 1	1 (reference)	0.92 (0.55-1.55)	1.32 (0.78-2.25)	0.346	1.003 (1.00-1.006)	0.090
Model 2	1 (reference)	0.98 (0.57-1.68)	1.24 (0.71-2.18)	0.647	1.003 (0.999-1.006)	0.153
Model 3	1 (reference)	1.03 (0.59-1.78)	1.28 (0.72-2.26)	0.650	1.002 (0.999-1.006)	0.169
CUN-BAE ≥median						
Crude model	1 (reference)	0.65 (0.42-1.0)	0.92 (0.60-1.41)	0.118	1.001 (0.998-1.004)	0.476
Model 1	1 (reference)	1.24 (0.68-2.27)	2.09 (1.13-3.87)	0.053	1.009 (1.005-1.013)	<0.0001
Model 2	1 (reference)	1.34 (0.70-2.54)	1.62 (0.84-3.09)	0.342	1.008 (1.003-1.012)	0.001
Model 3	1 (reference)	1.35 (0.71-2.58)	1.64 (0.85-3.14)	0.322	1.007 (1.003-1.01)	0.001
ABSI ≥median						
Crude model	1 (reference)	0.67 (0.43-1.02)	0.71 (0.46-1.08)	0.136	0.998 (0.995-1.001)	0.160
Model 1	1 (reference)	0.77 (0.48-1.23)	0.75 (0.47-1.20)	0.425	0.999 (0.996-1.002)	0.400
Model 2	1 (reference)	0.79 (0.49-1.28)	0.74 (0.46-1.21)	0.455	0.999 (0.996-1.002)	0.416
Model 3	1 (reference)	0.80 (0.50-1.29)	0.75 (0.46-1.22)	0.470	0.999 (0.996-1.002)	0.413

[a,b]Derived from univariate multiple logistic regression. Model 1=Adjusted for age and sex; Model 2=Further adjustment for sleep duration (hour/day), smoking status (category), total daily physical activity (category), education level (category) and occupation (category); Model 3 was additionally adjusted for global dietary index. BMI=Body mass index; 24-UNa=24-h urinary sodium; WC=Waist circumference; WHtR=Waist-to-height ratio; CUN-BAE=Clínica Universidad de Navarra–Body Adiposity Estimator; ABSI=A body shape index

with the increased risk of overweight or obesity either in crude (P = 0.017) or adjusted models (P = 0.015) and in adjusted model for abdominal obesity (P = 0.031) and enlarged CUN-BAE in adjusted model (P = 0.001). ABSI and WHtR were not significantly related to 24-UNa.

Table 5 shows the association between 24-UNa and anthropometric measures stratified by sex. In males, greater 24-UNa was associated with increased risk of having greater scores of CUN-BAE in the crude and first adjusted models. However, adjustment for further confounders eliminated the significance. Other anthropometric measures either in crude or different adjusted models were not associated with 24-UNa. When 24-UNa was considered as a continuous variable in analysis, it was slightly but significantly associated with the increased risk of abdominal adiposity and having higher scores of CUN-BAE in men. In women, 24-UNa was not associated with different anthropometric measures except for ABSI which was inversely related to 24-UNa. However, when 24-UNa was considered as a continuous variable in analysis and after adjustment for potential confounders, it was slightly but significantly associated with the increased risk of overweight and obesity, having greater scores of CUN-BAE, and decreased risk of enlarged ABSI in women.

Specificity, sensitivity, and overall accuracy for various obesity indices in the full-adjusted model are reported in Table 6. All indices had large specificity, sensitivity, and overall accuracy with 24-UNa either in categorical or continuous model. In both categorical and continuous models of 24-UNa, the highest specificity and sensitivity values were observed for CUN-BAE (in categorical model: 82.4% and in continuous model: 84.1%) and enlarged WC (in categorical model: 85.1% and in continuous model: 87.8%), respectively. The highest overall accuracy was observed for CUN-BAE (in categorical model: 84.9% and in continuous model: 85.3%).

DISCUSSION

The current study reveals a positive association between 24-UNa and body weight, BMI, and CUN-BAE as an estimator of body fat percentage. We found that participants in the highest tertile of 24-UNa had greater odds of being overweight or obese, but adjustment for potential confounders weakened this association and led to a marginally significant relationship. Each additional mEq/day 24-UNa excretion was associated with significant increment in the odds of overweight or obesity, abdominal obesity, and having greater CUN-BAE.

Our estimated associations are relatively consistent with those reported in earlier studies. As in our study, participants in the higher categories of salt intake had greater means of BMI, WC, and weight in different populations.[4-6] However, the magnitude of odds for being overweight was different between studies.[4,6,16] While the lowest increment in the odds of overweight per each additional mEq/day UNa excretion was observed in our study population, the greatest was found in NYC women (0.4% vs. 39% increment, respectively) after controlling for various confounders.[6] In the INTERMAP Study, salt intake was also differently and positively associated with BMI in Japan, China, United Kingdom, and United States. Zhou *et al*. demonstrated that each additional g/day salt intake was associated with greater BMI by 0.28 in Japan, 0.10 in China, 0.42 in the United Kingdom, and 0.52 in the United States.[16] Moreover, they found that higher salt intake was associated with greater prevalence of obesity in all four nations.[16] In Korean adults, men who were in the highest quintile of 24-UNa in comparison with those in the first quintile had 67% greater odds for obesity, whereas the corresponding value for women was 31% with a trend toward significance (P = 0.058).[32] Large specificity and sensitivity values for different obesity indices strongly confirm the potential role of sodium intake in relation to obesity indices.

The direct link between sodium intake and body fat in our study population is in line with findings reported in UK adults, in which each additional 1 g/day salt intake was associated with 0.91 kg increment in body fat in adults.[4] Consistently, the results of a national survey among Korean children and adolescents[15] and a multiethnic cohort[14] suggested a significant positive link between sodium intake and body fat percentage when determined by DEXA. To the best of our knowledge, there is little evidence regarding the association of salt intake and body fat. Although this study could not reveal any significant association for 24-UNa with ABSI and WHtR, this finding could not attenuate the relevance of the relationship between sodium and adiposity measurements. In our previous study, we showed that ABSI is strongly correlated with WHtR, and both of them were weakly related to cardiovascular risk factors, whereas CUN-BAE and BMI were better predictors of cardiovascular disease risk factors.[33] Therefore, it might be concluded that ABSI, unlike CUN-BAE, could not be an appropriate anthropometric index to measure trunk fat at least among Iranians.

The exact mechanisms underlying the association of sodium and obesity are not well established. However, the well-known mechanism is consuming higher amount of sugar-sweetened beverages following greater sodium intake to quench thirst. In addition, salty foods are mainly high in fat and energy density and have more palatability which encourage to overeating.[34] Other possible mechanism is having unhealthy lifestyle in individuals who consume more salt, like having a sedentary lifestyle and unhealthy food choices.[35] Moreover, higher sodium intake is

Table 5: Adjusted odds ratio (95% confidence interval) for obesity, abdominal obesity, and greater body fat according to tertiles of urinary sodium excretion

Variables	24-UNa			P^a	Continuous	P^b
	Tertile 1	Tertile 2	Tertile 3			
Male						
BMI ≥25 kg/m^2						
Crude model	1 (reference)	0.74 (0.37-1.49)	1.59 (0.79-3.19)	0.056	1.003 (1.00-1.007)	0.076
Model 1	1 (reference)	0.83 (0.40-1.69)	1.67 (0.82-3.41)	0.084	1.004 (1.00-1.008)	0.057
Model 2	1 (reference)	0.72 (0.34-1.51)	1.17 (0.54-2.57)	0.376	1.001 (0.997-1.006)	0.513
Model 3	1 (reference)	0.78 (0.37-1.66)	1.19 (0.54-2.63)	0.508	1.001 (0.997-1.006)	0.538
WC ≥102 cm						
Crude model	1 (reference)	3.84 (0.82-18.08)	5.33 (1.16-24.50)	0.097	1.009 (1.00-1.014)	0.001
Model 1	1 (reference)	4.51 (0.94-21.65)	5.79 (1.24-27.05)	0.082	1.009 (1.004-1.015)	0.001
Model 2	1 (reference)	4.04 (0.84-19.50)	4.73 (0.96-23.33)	0.154	1.010 (1.003-1.016)	0.003
Model 3	1 (reference)	4.19 (0.86-20.32)	4.80 (0.97-23.61)	0.147	1.010 (1.003-1.016)	0.003
WHtR ≥0.5						
Crude model	1 (reference)	0.86 (0.43-1.72)	1.68 (0.82-3.48)	0.108	1.003 (0.999-1.007)	0.170
Model 1	1 (reference)	1.06 (0.50-2.26)	1.89 (0.86-4.14)	0.166	1.003 (0.999-1.008)	0.126
Model 2	1 (reference)	1.16 (0.53-2.52)	1.75 (0.75-4.05)	0.392	1.003 (0.998-1.007)	0.248
Model 3	1 (reference)	1.42 (0.63-3.21)	1.87 (0.78-4.47)	0.368	1.003 (0.998-1.008)	0.248
CUN-BAE ≥median						
Crude model	1 (reference)	1.01 (0.31-3.27)	2.74 (0.95-7.91)	0.040	1.009 (1.004-1.015)	0.001
Model 1	1 (reference)	1.20 (0.36-3.98)	3.06 (1.03-9.10)	0.043	1.010 (1.005-1.016)	<0.0001
Model 2	1 (reference)	1.13 (0.33-3.85)	1.94 (0.60-6.32)	0.437	1.008 (1.001-1.014)	0.016
Model 3	1 (reference)	1.14 (0.33-3.89)	1.95 (0.60-6.36)	0.434	1.008 (1.001-1.014)	0.016
ABSI ≥median						
Crude model	1 (reference)	0.998 (0.50-1.99)	1.30 (0.65-2.61)	0.642	1.001 (0.997-1.005)	0.567
Model 1	1 (reference)	1.29 (0.60-2.78)	1.46 (0.68-3.13)	0.624	1.002 (0.998-1.006)	0.435
Model 2	1 (reference)	1.47 (0.66-3.26)	1.68 (0.72-3.92)	0.460	1.003 (0.999-1.008)	0.175
Model 3	1 (reference)	1.52 (0.68-3.40)	1.71 (0.73-3.99)	0.437	1.003 (0.999-1.008)	0.173
Female						
BMI ≥25 kg/m^2						
Crude model	1 (reference)	1.01 (0.58-1.77)	1.53 (0.87-2.69)	0.275	1.004 (1.00-1.008)	0.040
Model 1	1 (reference)	1.21 (0.65-2.26)	1.96 (1.05-3.67)	0.102	1.007 (1.002-1.011)	0.004
Model 2	1 (reference)	1.30 (0.67-2.52)	2.11 (1.09-4.11)	0.085	1.007 (1.002-1.012)	0.003
Model 3	1 (reference)	1.22 (0.63-2.40)	1.99 (1.01-3.92)	0.131	1.007 (1.002-1.012)	0.005
WC ≥88 cm						
Crude model	1 (reference)	0.97 (0.55-1.71)	0.84 (0.48-1.47)	0.823	1.00 (0.996-1.003)	0.815
Model 1	1 (reference)	1.15 (0.61-2.16)	0.97 (0.52-1.80)	0.853	1.001 (0.997-1.005)	0.641
Model 2	1 (reference)	1.21 (0.63-2.33)	0.99 (0.52-1.90)	0.815	1.001 (0.997-1.006)	0.576
Model 3	1 (reference)	1.11 (0.57-2.17)	0.91 (0.46-1.77)	0.851	1.001 (0.996-1.005)	0.750
WHtR ≥0.5						
Crude model	1 (reference)	0.77 (0.41-1.45)	0.89 (0.47-1.72)	0.108	1.001 (0.996-1.005)	0.766
Model 1	1 (reference)	0.78 (0.37-1.64)	0.94 (0.45-1.97)	0.800	1.002 (0.997-1.007)	0.405
Model 2	1 (reference)	0.78 (0.35-1.74)	0.92 (0.41-2.07)	0.833	1.002 (0.997-1.008)	0.417
Model 3	1 (reference)	0.64 (0.28-1.47)	0.76 (0.33-1.77)	0.574	1.001 (0.996-1.007)	0.645
CUN-BAE ≥median						
Crude model	1 (reference)	1.09 (0.57-2.10)	1.28 (0.66-2.51)	0.764	1.004 (0.999-1.009)	0.119
Model 1	1 (reference)	1.21 (0.53-2.76)	1.49 (0.66-3.37)	0.631	1.001 (1.001-1.013)	0.027
Model 2	1 (reference)	1.44 (0.60-3.44)	1.54 (0.64-3.71)	0.568	1.008 (1.001-1.014)	0.021
Model 3	1 (reference)	1.25 (0.51-3.07)	1.31 (0.53-3.26)	0.818	1.007 (1.000-1.013)	0.045
ABSI ≥median						
Crude model	1 (reference)	0.56 (0.32-0.99)	0.49 (0.28-0.66)	0.028	0.995 (0.991-0.999)	0.016
Model 1	1 (reference)	0.59 (0.33-1.08)	0.51 (0.28-0.93)	0.064	0.996 (0.992-1.000)	0.046
Model 2	1 (reference)	0.57 (0.31-1.06)	0.47 (0.25-0.88)	0.045	0.995 (0.991-0.999)	0.020
Model 3	1 (reference)	0.55 (0.29-1.03)	0.45 (0.24-0.86)	0.036	0.995 (0.990-0.999)	0.016

[a,b]Derived from univariate multiple logistic regression. Model 1=Adjusted for age and sex; Model 2=Further adjustment for sleep duration (hour/day), smoking status (category), total daily physical activity (category), education level (category) and occupation (category); Model 3 was additionally adjusted for global dietary index. BMI=Body mass index; 24-UNa=24-h urinary sodium; WC=Waist circumference; WHtR=Waist-to-height ratio; CUN-BAE=Clínica Universidad de Navarra–Body Adiposity Estimator; ABSI=A body shape index

Table 6: Specificity, sensitivity and overall accuracy for obesity indices in the full adjusted model[a]

	24-UNa	
	Categorical model	Continuous model
BMI ≥25 kg/m^2		
Specificity	67.1	69.2
Sensitivity	73.2	71.7
Overall accuracy	70.3	70.5
WC ≥88 cm in women and 102 in men		
Specificity	85.1	83.4
Sensitivity	61.2	64.5
Overall accuracy	76.2	76.4
WHtR ≥0.5		
Specificity	54.8	54.2
Sensitivity	87.8	87.8
Overall accuracy	77.4	77.2
CUN-BAE ≥median		
Specificity	82.4	84.1
Sensitivity	87.4	86.6
Overall accuracy	84.9	85.3
ABSI ≥median		
Specificity	74.0	73.2
Sensitivity	57.1	57.6
Overall accuracy	65.6	65.4

[a]Adjusted for age, sex, sleep duration (hour/day), smoking status (category), total daily physical activity (category), education level (category), occupation (category), and global dietary index. BMI=Body mass index; 24-UNa=24-h urinary sodium; WC=Waist circumference; WHtR=Waist-to-height ratio; CUN-BAE=Clínica Universidad de Navarra–Body Adiposity Estimator; ABSI=A body shape index

associated with retention of water in the body and therefore leads to more estimation of body weight. Although the main mechanism is greater energy intake by individuals who consume higher sodium, an animal model study suggested that sodium could change glucose and insulin metabolism and thereby change fat mass, independent of energy intake.[36,37] Finally, elevated levels of cortisol in individuals with abdominal obesity[38] and also the positive link between UNa excretion and urinary free cortisol and total cortisol metabolites[39] may provide more explanation regarding the association between salt and obesity.

The major strengths of the current study included the use of 24-UNa rather than dietary intake sodium estimated by FFQ or recall. 24-UNa is the "gold standard" method to assess the salt intake in epidemiological surveys because dietary tools are prone to underreporting bias.[40] Moreover, we assessed different anthropometrics measures. Although BMI is the most widely anthropometric measures to estimate obesity, it has several limitations such as not considering any difference between muscle and fat mass.[10] To date, only few studies have assessed body fat in relation to sodium intake, and we evaluated CUN-BAE and ABSI as measurements of body fat. This study was limited by several ways. First, the lack of precise data on energy intake may mislead our findings. Nevertheless, we controlled the effects of SSB on anthropometric measures as a proxy measure of energy intake that is suggested as a possible mechanism to mediate the association of sodium intake and obesity. Second, the cross-sectional design of this study does not allow us to establish the causality between 24-UNa and obesity. To confirm these associations, longitudinal and experimental studies are required to explore the impact of 24-UNa on anthropometric measures. Third, due to financial limitations, we only obtained a single 24-h urine sample to estimate dietary salt intake which may not exactly reflect the common intake of salt in participants. However, the consistence between our results and other studies might confirm the true associations in our study. Fourth, in spite of controlling for different confounders, some residual or unmeasured variable may affect our results.

CONCLUSION

Greater 24-UNa excretion was associated with greater means of body weight, BMI, WC, and CUN-BAE. However, increasing the 24-UNa by the tertiles was not significantly associated with increased risk of having greater anthropometric measures. Our results revealed small changes in anthropometric measures per each additional 24-UNa excretion; however, due to obesity epidemic, exploring wide-ranging strategies to reduce sodium intake in the community may be useful to prevent obesity as well as hypertension. Prospective studies with larger sample size are warranted to confirm the association of salt with obesity among Iranians.

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Conflicts of interest
There are no conflicts of interest.

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