Journal of Nutrition and Food Security
Shahid Sadoughi University of Medical Sciences
School of Public Health
Department of Nutrition
Nutrition & Food Security Research Center

eISSN: 2476-7425 pISSN: 2476-7417 JNFS 2019; 4(3): 191-199 Website: jnfs.ssu.ac.ir

[DOR: 20.1001.1.24767417.2019.4.3.1.3]
[DOI: 10.18502/jnfs.v4i3.1311]

Sodium Status and Its Association with Overweight and Obesity in Adults Living in Yazd, Iran

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ARTICLE INFO

ORIGINAL ARTICLE

Article history:
Received: 25 Jun 2018
Revised: 3 Sep 2018
Accepted: 26 Dec 2018

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ABSTRACT

Background: Studies on the relationship of urinary sodium with overweight and obesity led to controversial results. Furthermore, no study has ever investigated the association between sodium status and obesity in Iranian adults. The present study examined the association of urinary sodium levels with overweight and obesity in adults living in Yazd, Iran. ***Methods:*** The present study recruited 240 adults randomly selected from adults, who participated in Yazd Health Study (YaHS). A 24-hour urine sample was collected from the participants. Participants' demographic information, history of chronic diseases, and smoking status were obtained. The height and weight of the participants were also assessed using standard methods. We compared the weight and body mass index (BMI) of the participants based on the urinary sodium excretion tertiles. The logistic regression model in crude and multivariable adjusted models was used to compare the odds of obesity between urinary sodium tertiles. ***Results:*** The findings showed that the mean urinary sodium was not significantly different among overweight, obese, and individuals with normal BMI ($P > 0.05$) using the crude and multivariable models. Furthermore, no significant difference was observed in the mean BMI according to urinary sodium excretion tertiles. In addition, the analyses showed that the sodium status was not significantly associated with odds of developing obesity in crude and in multivariable adjusted models. ***Conclusion:*** No significant relationship was seen between sodium status and overweight or obesity. Future prospective studies are highly recommended to confirm these results.

***Keywords**: Sodium status; Overweight; Obesity*

Introduction

Overweight and obesity are still considered as health and social dilemma in the current century and have a growing trend in many countries (Gallus *et al.*, 2013). Studies in Iran

This paper should be cited as: Dashti- Rahmat Abadi A, Mozaffari- Khosravi H, Nemayandeh M, Soltani MH, Mirzaei M, Salehi Abargouei A**. *Sodium Status and its Association with Overweight and Obesity in Adults Living in Yazd, Iran.*** *Journal of Nutrition and Food Security (JNFS),* 2019; 4 (3): 191-199.

show that obesity is a health problem (Hosseini-Esfahani *et al.*, 2010). According to a case study conducted in 2015 in Iran, the prevalence of obesity was estimated as 21.7% in adults. (Rahmani *et al.*, 2015). It was also found that the risk of obesity was higher in Iranian women (26.2%) compared to the Iranian men (12.9%) (Kelishadi *et al.*, 2014).

Several factors are associated with obesity and overweight. Several genetic and environmental factors may cause obesity. According to a study on identical twins, obesity was under the influence of genes by only 20-30% and the growth of obesity was mainly affected by people's food habits and lifestyles (Vohl *et al.*, 2000). Nutrition and physical activity are among the important environmental factors related to obesity. As an example, some food groups such as dairy, fruits, and vegetables have inverse relationship with obesity and overweight (Brooks *et al.*, 2006). Moreover, a number of food groups such as red meat, fast foods, and processed meat were found to have direct association with obesity (Lorenzen *et al.*, 2007). On the other hand, the relationship of several micronutrients such as vitamin C, calcium, and vitamin D with was confirmed (Parikh and Yanovski, 2003). The relationship of sodium with obesity and overweight was largely investigated in recent years. In this regard, the relationship between sodium and overweight was confirmed (Strazzullo *et al.*, 2001). For instance, a study on the adult population of Spain showed that people with more sodium excretion had a higher BMI compared to people with less sodium excretion (Navia *et al.*, 2014). Another study on Korean children indicated that people with a higher density of sodium intake had a higher general and abdominal obesity compared to the group with a less sodium intake density. In addition, a positive relationship was found between increased sodium intake and increased risk of overweight in adults as a result of consuming extra sodium in their common foods such as soup, kimchee, and fish (Bolhuis *et al.*, 2012, Fonseca-Alaniz *et al.*, 2007, Fonseca- Alaniz *et al.*, 2007, Oh *et al.*, 2017).

The relationship of sodium with obesity may be due to the fact that salty foods have higher amounts of energy. Increased sodium causes increased palatability of food, which leads to a kind of willingness to take higher calories (Bolhuis *et al.*, 2012). Moreover, researchers believe that salt may function as a fat absorbent (Csabi *et al.*, 1996). In addition, the findings of animal studies show that high sodium diet increased tissue fat mass and changed the insulin and glucose metabolism, which might lead to fat accumulation (Fonseca- Alaniz *et al.*, 2008).

To the best of our knowledge, no study has ever investigated the relationship between 24-hour sodium excretion, as a strong indicator of sodium intake, and obesity in Iran. Furthermore, the results of the related studies are controversial. So, the present study was conducted to evaluate the relationship of urinary sodium with general and abdominal obesity in adults living in Yazd.

Material and Methods

Design and participants: The study population consisted of 240 people selected from 10,000 people who participated in Yazd health survey (YaHS) (Mirzaei *et al.*, 2017). The participants were randomly selected and their amount of 24-hour urinary sodium was determined. Their demographic, socio-economic, lifestyle and anthropometric information were available regarding to YaHS protocol.

The inclusion criteria were having 18 years of age and over as well as signing the informed consent form. In the case that participants were on a special diet or were younger than 18 years, they were excluded from the study.

*Measurements***:** The participants' height and weight were measured and their BMI rates were calculated (weight in kilogram divided by height in meter squared). The participants' height was measured in standing position and without shoes using a wall mounted non-stretchable meter with a precision of 0.5cm. The weight was measured using a scale (Omron, Japan) with a precision of 100g. Overweight and obesity were defined as BMI of 25-29.9 and above 30, respectively.

To assess the 24-hour urine samples, each participant was provided with a 2.5 liter polypropylene container as well as written and oral instructions to fill the urine containers. To begin urine collection, participants were asked to excrete their first urine volume at the beginning of the day. Later, they were asked to collect their urine in the provided container 24 hours later. Participants were required to avoid consuming medications, since medications might affect their renal excretion or kidney filtration during the research.

The collected samples were taken to laboratory in the next morning. The urine creatinine and salt volume were analyzed in these samples. The creatinine content in the 24-hour urine samples were compared between males and females.

The amount of urine sodium intake was reported in meq/L. The amount of 24-hour sodium was calculated according to the volume of urine collected in 24 hours and based on mg/lit scale. The approximate amount of salt intake in 24 hours was also calculated based on the molecular mass. This led to an estimation of the amount of daily salt consumption of the participants. The calculations were conducted using the following formula:

Na (meq.lit) ×23=Na (mg.lit)

Na (mg.lit) ×urine volume24h=Na (mg.24h)

Na (mg.24h) ×2.6 = NaCl (mg.24h)

The urine sodium density was measured by an auto-analyzer machine.

Other variables such as participants' smoking status, education level, and history of chronic disease were also collected from the YaHS and evaluated (Mirzaei *et al.*, 2017).

Data analysis: The data were analyzed using SPSS version 16. The normal distribution of the quantitative data was assessed by Kolmogrov-Smirnov test. To compare the quantitative and qualitative variables among people with normal weight, overweight, and obesity, the analysis of variance (ANOVA) and Chi-square tests were used, respectively.

Average 24-hour sodium intakes of individuals with normal weight, overweight, and obesity were initially used as the raw data. Later, these data were compared using the analysis of covariance (ANCOVA) test to adjust for the confounding variables. Logistic regression was also applied in crude and multivariable adjusted models to compare the odds of developing overweight and obesity based on the tertiles of the measured sodium intake. P values of less than or equal to 0.05 were considered as statistically significant.

Ethical considerations: The current study was approved by the Ethics Committee of Shahid Sadoughi University of Medical Sciences, Yazd, Iran. All people involved in the current study were well informed about the research objectives and filled the informed written consent forms.

Results

In total, 240 participants cooperated in the study with an average age of 47.69 years. The participants included 110 men with the average age of 48.54 ± 1.29 years and 130 women with the average age of 46.96 ± 1.20 years. The general characteristics of participants based on gender are provided in **Table 1**.

As it is observed in **Table 1**, the only significant difference between males and females was in the average systolic blood pressure (P > 0.001). The average systolic blood pressure was 128.81 ± 19.50 mmHg in males, but it was 118.18 ± 18.28 mmHg in females. The present study also showed that men excreted more amounts of urine creatinine compared to women. The amount of urinary creatinine excretion was 1062.80 ± 35.85 milligram per deciliter for men and 951.42 ± 28.87 for women (P = 0.029).

The participants were also significantly different regarding their smoking status. The findings showed that 27%.3 of men and 10%.8 of women had a history of smoking (P = 0.001).

Table 2 provides the data about the comparison of 24-hour urinary sodium (Na), based on the participants' BMI status between the total number of participants as well as the participants with no history of chronic diseases including cardiovascular diseases, diabetes, and blood pressure. Considering the total number of people who participated in the study, urinary sodium excretion was not significantly different among participants with normal BMI, overweight, and obesity (P = 0.701). No significant difference was observed among participants with normal BMI, overweight, and obesity after adjusting for the confounding variables such as age, smoking, chronic diseases, and gender ($P < 0.05$). When the analyses were restricted to participants with no chronic diseases (N=162), no significant difference was observed neither in the total number of participants nor based on gender divisions. ($P < 0.05$).

The average weight based on the urinary sodium tertiles is reported in **Table 3**. The analysis showed that the average weight was not significantly different among sodium intake tertiles neither for the total number of participants nor for men and women ($P = 0.617$). Such a relationship was not observed in people without chronic diseases ($P = 0.685$). This relationship remained the same even after adjusting for the probable confounding variables such as age, gender, and smoking ($P = 0.677$).

Comparison of average urinary sodium in healthy people based on gender showed that weight was not significantly different based on the urinary sodium tertiles neither in men nor in women.

Average BMI based on urinary sodium tertiles is reported in **Table 4**. The results showed that the average BMI was not significantly different between the sodium intake tertiles neither in the total number of participants nor in men and women ($P = 0.683$).

This finding was also observed in people with no chronic diseases ($P = 0.587$). This relationship remained the same after adjustment for the probable confounding variables such as age, gender, and smoking ($P = 0.502$).

The odds of overweight based on sodium excretion tertiles is reported in Table 4. The analysis showed that the odds of overweight or obesity was 34% higher for people in the highest density of 24-hour urinary sodium, but this relationship was not significant [OR = 1.34, 95% confidence interval (CI): 0.70 = 2.56]. The analyses based on gender and among participants with no chronic diseases also led to the same results.

Table 1. General characteristics of the study participants based on gender

Variables	Males (Number = 110)	Females (Number = 130)	Total (Number = 240)	P- value
Age (year)	48.54 ± 13.61[a]	46.96 ± 13.68	47.69 ± 13.64	0.684
Height (cm)	170.74 ± 8.64	155.74 ± 7.40	162.47 ± 8.02	0.099
Weight (kg)	77.87 ± 14.95	68.97 ± 13.75	73.05 ± 14.35	0.420
Systolic blood pressure (mmHg)	128.81 ± 19.50	118.18 ± 18.28	123.05 ± 80.60	0.001
Diastolic blood pressure (mmHg)	82.22 ± 10.43	79.22 ± 12.12	80.59 ± 11.45	0.043
Body mass index (kg/m^2)	26.77 ± 4.77	28.54 ± 5.48	27.73 ± 5.12	0.062
Urinary sodium	126.72 ± 42.17	121.14 ± 41.58	123.70 ± 41.87	0.633
Urine volume (mL)	1358.09 ± 1350.87	1173.15 ± 429.72	1257.91 ± 889.93	0.110
Urinary creatinine	1062.80 ± 376.21	951.42 ± 379.23	1002. 47 ± 377.50	0.029
History of being diagnosed with high blood pressure (%)	24.5	20.8	22.5	0.485
History of being diagnosed with diabetes (%)	18.2	14.6	16.3	0.408
History of being diagnosed with cardiovascular diseases (%)	9.1	5.4	7.1	0.265
Smoking (%)	27.3	10.8	18.3	0.001

[a] *: Mean ± SD*

Table 2. Density of urinary sodium based on participants' BMI status before and after modifying the confounding variables (the values are reported as mean±standard error).

	Normal	Overweight	Obese	P-value
Total participants	Number = 76	Number = 91	Number = 71	
Crude model	122.38 ± 4.83	126.65 ± 4.41	121.51 ± 5.00	0.701
Adjusted model	123.61 ± 5.29	125.50 ± 4.53	121.64 ± 5.29	0.854
Males				
Crude model	121.59 ± 6.80	131.62 ± 6.13	125.64 ± 9.06	0.545
Adjusted model[a]	121.32 ± 12.7	31.89 ± 25.61	125.53 ± 9.39	0.547
Females				
Crude model	123.21 ± 6.91	121.1 ± 6.41	119.65 ± 6.00	0.927
Adjusted model[b]	123.50 ± 7.97	121.92 ± 6.72	118.59 ± 6.41	0.884
People without any chronic disease	Number = 65	Number = 58	Number = 39	
Males and females				
Crude model	122.41 ± 5.22	131.87 ± 5.53	122.00 ± 6.74	0.382
Adjusted model[c]	124.43 ± 5.55	130.48 ± 5.65	120.70 ± 7.11	0.525
Males				
Crude model	119.63 ± 7.60	138.32 ± 7.84	123.10 ± 13.81	0.223
Adjusted model[d]	120.79 ± 7.75	138.30 ± 7.97	119.33 ± 14.05	0.247
Females				
Crude model	125.28 ± 7.26	124.44 ± 7.90	121.62 ± 7.62	0.937
Adjusted model[d]	128.18 ± 8.12	124.11 ± 8.08	118.72 ± 8.01	0.734

[a:] Adjusted for age, gender, smoking, and chronic diseases (high blood pressure, diabetes, and cardiovascular diseases); [b:] Adjusted for age, smoking status, and chronic diseases (high blood pressure, diabetes, and cardiovascular diseases); [c:] Adjusted for age, gender, smoking status; [d:] Adjusted for age and smoking status

Table 3. Average weight based on urinary sodium tertiles (the values are reported as mean±standard error)

	Urinary sodium amounts			
	T1	T2	T3	P value
Total participants				
Crude model	72.31 ± 1.65	74.10 ± 1.69	72.82 ± 1.67	0.747
Adjusted model[a]	72.80 ± 1.59	74.05 ± 1.63	72.44 ± 1.60	0.764
Males				
Crude model	76.1 ± 2.50	78.64 ± 2.47	78.82 ± 2.47	0.692
Adjusted model[b]	75.66 ± 2.58	79.11 ± 2.50	78.80 ± 2.51	0.590
Females				
Crude model	69.33 ± 2.03	69.95 ± 2.15	67.65 ± 2.10	0.732
Adjusted model[b]	69.31 ± 2.02	70.34 ± 2.17	67.41 ± 2.10	0.617
Participants without chronic disease				
All participants				
Crude model	70.91 ± 2.03	73.08 ± 2.07	70.89 ± 1.97	0.685
Adjusted model[c]	71.19 ± 1.97	73.02 ± 2.00	70.66 ± 1.91	0.677
Males				
Crude model	73.28 ± 2.89	75.78 ± 3.02	77.36 ± 2.84	0.601
Adjusted model[d]	72.79 ± 2.97	76.05 ± 3.08	77.58 ± 2.88	0.511
Females				
Crude model	68.86 ± 2.69	70.93 ± 2.69	65.45 ± 2.60	0.338
Adjusted model[d]	69.22 ± 2.57	71.26 ± 2.56	64.79 ± 2.50	0.191

[a:] Adjusted for age, gender, smoking, and chronic diseases (high blood pressure, diabetes, and cardiovascular iseases); [b:] Adjusted for age, smoking status, and chronic diseases (high blood pressure, diabetes, and cardiovascular diseases); [c:] Adjusted for age, gender, smoking status; [d:] Adjusted for age and smoking status

[DOI: 10.18502/jnfs.v4i3.1311]

Table 4. Average BMI based on urinary sodium tertiles (the values are reported as mean±standard error)

	Urinary sodium amounts			
	T1	**T2**	**T3**	**P value**
All participants				
Crude model	27.62 ± 0.57	28.15 ± 0.59	27.45 ± 0.58	0.683
Adjusted model[a]	727.86 ± 0.53	328.00 ± 0.55	27.31 ± 0.543	0.644
Males				
Crude model	36.56 ± 0.80	26.97 ± 0.79	26.78 ± 0.79	0.936
Adjusted model[b]	226.75 ± 0.79	26.72 ± 0.77	26.85 ± 0.77	0.993
Females				
Crude model	28.44 ± 0.81	29.21 ± 0.85	28.02 ± 0.83	0.606
Adjusted model[b]	28.52 ± 0.74	29.37 ± 0.79	27.75 ± 0.76	0.351
People without chronic diseases				
All participants				
Crude model	26.71 ± 0.70	27.45 ± 0.71	26.46 ± 0.68	0.587
Adjusted model[c]	27.08 ± 0.64	27.28 ± 0.65	26.27 ± 0.62	0.502
Males				
Crude model	25.37 ± 0.82	25.50 ± 0.85	26.14 ± 0.80	0.776
Adjusted model[d]	25.60 ± 0.82	25.22 ± 0.85	26.16 ± 0.79	0.719
Females				
Crude model	27.86 ± 1.06	29.01 ± 1.06	26.74 ± 1.03	0.316
Adjusted model[d]	28.12 ± 0.93	29.22 ± 0.93	26.30 ± 0.91	0.086

[a:]Adjusted for age, gender, smoking, and chronic diseases (high blood pressure, diabetes, and cardiovascular iseases);[b:]Adjusted for age, smoking status, and chronic diseases (high blood pressure, diabetes, and cardiovascular diseases); [c:]Adjusted for age, gender, smoking status; [d:]Adjusted for age and smoking status

Table 5. The odds of overweight or obesity based on urinary sodium density tertiles; the values are reported as mean±standard error.

	Urinary sodium amounts			
	T1	T2 OR (95%CI)	T3 OR (95%CI)	P for trend
All participants				
Crude model	1	1.70 (0.86-3.35)	1.34 (0.70-2.56)	0.301
Adjusted model[a]	1	1.58 (0.73-3.39)	1.19 (0.57-2.51)	0.508
Males				
Crude model	1	1.6 (0.62-4.16)	1.89 (0.72-4.96)	0.398
Adjusted model[b]	1	1.42 (0.47-4.25)	2.14 (0.71-6.45)	0.403
Females				
Crude model	1	1.96 (0.72-5.21)	1.00 (0.41-2.43)	0.351
Adjusted model[b]	1	2.71 (0.82 – 8.98)	0.92 (0.30-2.83)	0.184
People without chronic diseases				
Males and females				
Crude model	1	1.45 (0.67-3.17)	1.48 (0.68-3.16)	0.527
Adjusted model[c]	1	1.21 (0.52-2.83)	1.25 (0.55-2.86)	0.851
Males				
Crude model	1	1.39 (0.45-4.33)	2.86 (0.91-9.02)	0.188
Adjusted model[d]	1	1.08 (0.32-3.61)	2.78 (0.83-9.32)	0.190
Females				
Crude model	1	1.53 (0.50-4.64)	0.85 (0.30-2.38)	0.557
Adjusted model[d]	1	1.90 (0.51-7.08)	0.65 (0.18-2.34)	0.311

[a:]Adjusted for age, gender, smoking, and chronic diseases (high blood pressure, diabetes, and cardiovasculardiseases);[b:]Adjusted for age, smoking status, and chronic diseases (high blood pressure, diabetes, and cardiovascular diseases); [c:]Adjusted for age, gender, smoking status; [d:]Adjusted for age and smoking status

Discussion

Overall, the present study showed that the average urinary sodium was not significantly different between normal BMI, overweight, and obese participants. Furthermore, no significant difference was observed in the average weight and

[DOR: 20.1001.1.24767417.2019.4.3.1.3]

[DOI: 10.18502/jnfs.v4i3.1311]

BMI of the urinary sodium tertiles. The analysis on people with no chronic diseases such as diabetes, high blood pressure, and cardiovascular diseases led to the same results.

The results of this study are comparable with a study by Oh et al. (Oh *et al.*, 2017). This research was conducted on 1846 adults participated in the national study of health and nutrition examination survey in Korea. Its results showed no relation between obesity and 24-hour urinary sodium excretion in people older than 75 years. No relationship was also found regarding the amount of body fat in people older than 65 years. However, this study showed a significant relationship between the body fat and the urinary sodium excretion in all participants.

Another multi-central study conducted in Korea found that sodium intake calculated by 24-hour food recall had no relationship with obesity in both genders (Nam *et al.*, 2017). On the other hand, this study showed a direct correlation between 24-hour sodium excretion and obesity, which was independent of the energy intake.

Several studies considered the excreted urinary sodium in association with obesity among children and teenagers and their results were contradictory. As an example, a study by Grimes et al. in 2016 on 666 school children from Australia showed that increasing 17% millimol of daily sodium intake is associated with a 23% increased odds of overweight or obesity (Grimes *et al.*, 2016). In return, another study over 60 children showed that children with obesity excreted less sodium compared to healthy ones (Csabi *et al.*, 1996).

Indeed, in the present study no relationship was observed between 24-hour urinary sodium and obesity or overweight. This study is the first research conducted on Iranian adults evaluating the relationship between urinary sodium and obesity or overweight status. Studies showed that the relationship between urinary sodium excretion and factors indicating the amount of body fat might be different according to people's race and lifestyle (Jain *et al.*, 2014). This finding shows the importance of evaluating this relationship in other communities with different races and ethnicities.

Some other studies were also conducted investigating the sodium to urinary potassium ratio and their relationships with obesity and overweight. As an example, in a prospective study on 2782 adults, Jain et al. showed that the urine sodium to urine potassium ratio was associated with the total body fat percentage, independent of any other confounding variable (Jain *et al.*, 2014). This relationship was found to be stronger in non-black people compared to American black individuals.

Different possible mechanisms were suggested for the relationship between urinary sodium excretion and obesity. Intake of higher amounts of sodium is considered as a reason of obesity because of receiving higher amounts of energy due to the sodium intake. Sodium intake may increase thirst and appetite; it results in a willingness to drink sweets and sweet drinks with high calories (Grimes *et al.*, 2013, He *et al.*, 2008). Animal studies showed that any exposure to sodium for a long time caused an increased glucose-to-fat conversion capacity. Moreover, the lipogenic enzyme activity of white fat cells might increase leptin production and hypertrophy of fat cells and consequently results in an excessive accumulation of fat (Fonseca- Alaniz *et al.*, 2008). Another study on rabbits showed that getting too much salt interrupted the effect of leptin on sympathetic activity and cardiovascular system (Mohammad *et al.*, 2010). Moreover, a cross-sectional study was carried out in America and showed the relationship of sodium intake with obesity and serum leptin levels (Zhu *et al.*, 2014). So, it seems that consuming sodium for a long time can cause an increase in production and resistance to leptin by changing homeostasis of the energy and accordingly increase the risks of obesity (Nam *et al.*, 2017).

A number of limitations existed that should be considered while interpreting results of the current study. The present study was a cross-sectional research in which causal associations cannot be inferred, because researchers cannot ensure if the independent variable occurred before the dependent variable(s). In the present study, we did

[DOR: 20.1001.1.24767417.2019.4.3.1.3]

[DOI: 10.18502/jnfs.v4i3.1311]

not have access to data on waist circumference and body fat percentage. Although we did not find any association between sodium status and general obesity, it would be interesting to study this association for abdominal obesity and body fat percentage.

Conclusion

In conclusion, the present study revealed that sodium intake was not associated with general obesity and overweight in adults. Future longitudinal studies with larger sample sizes should be conducted on abdominal obesity and overweight.

Acknowledgements

The present study was extracted from a thesis in order to getting the Master's degree in public health in nutrition. This project was funded by the international branch, Shahid Sadoughi University of Medical Sciences, Yazd, Iran. The author would like to appreciate all the professors involved in this research since this study would not effectively end up without their help.

Authors' contribution

All authors contributed in designing the study concept as well as preparing and writing this manuscript.

Conflict of interests

The authors declare no conflict of interest about this study.

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