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Trend of salt intake measured by 24-hour urine collection samples among Iranian adults population between 1998 and 2013: The Isfahan salt study

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Abstract *Background and aim:* Few population-based studies conducted in the Eastern Mediterranean region assessed salt intake by the measurement of 24-h sodium urine excretion (24-hUNa). The current study aimed to assess the trend of mean salt intake in Iranian adults between 1998 and 2013.
Methods and results: These cross-sectional studies were performed on 564, 157, 509 and 837 randomly selected healthy adults aged >18 years from Isfahan city, Iran, in 1998, 2001, 2007 and 2013, respectively. BP was measured using a mercury sphygmomanometer according to a standard protocol. Single 24-h urine was collected to assess 24-hUNa as a surrogate of salt intake, and 24-h urinary K (24-hUK).

The estimated trend of salt intake was 9.5, 9.7, 9.6 and 10.2 g/day in total population ($P < 0.001$). The increase in salt intake between 1998 and 2013 was significant only in men, ($P < 0.001$). The risk of pre-hypertension was 21% and 18% significantly greater in the highest quartiles of UNa/UK after adjustment for potential confounders in 2001 and 2013, respectively, [OR (95% CI): 1.21 (1.03–1.64) and 1.18 (1.02–1.38), respectively].
Conclusions: This population-based study indicated that mean salt intake was about two times of recommendation in Isfahan city, Iran, and suggest that it would be essential to implement a salt reduction strategy program in Iranian population. Longitudinal national studies with larger samples examining the trend of salt intake are warranted.

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Introduction

Non-communicable diseases (NCDs) are the main public health problem worldwide [1]. It has been predicted that NCDs may cause about 80% of deaths in developing countries by 2020 [2]. Amongst NCDs, cardiovascular disease (CVD) is the leading cause of death and disability in developed and developing countries [3]. Hypertension is the most important contributor to CVD events in Iranian population [4]. The hypertension prevalence is 17.3% among Iranian adults [5]. Genetic and environmental factors and their interactions are shown to be determinants of the development of hypertension [6]. Diet seems to have a major role in blood pressure (BP) regulation [7]. Epidemiologic and pathophysiologic evidences support a casual association between excessive salt intake and raising BP, as well as other NCDs such as chronic renal disease, CVD, gastric cancer, osteoporosis and even obesity [8–11]. The World Health Organization (WHO) recommended less than 5 g/day intake for salt [12]. However, as it may unfeasible in most countries, WHO reported a 30% decrease in salt intake by 2025 as one of the 9 goals determined as the most cost-effective strategy for the prevention of hypertension as well as other NCDs in all countries and regions [13]. Although there is limited reliable national report on salt consumption, convenient data pointed out that average salt intake was 9–12 g/day in many populations [14] and it was even more than 12 g/day in most Eastern European and Asian countries [14]. A previous study indicated that Iranian's salt intake, estimated by a food frequency questionnaires, was more than twice of that recommended [15] and such high salt intake could be one of the main dietary problems of Iranians.

Generally, different dietary assessment methods underestimate salt and sodium (Na) intake, however, 24-h (24-h) urine collection has been considered as the gold standard and the most accurate and reliable method [16].

In order to help with setting policies for salt reduction intake in Iran, the Isfahan Cardiovascular Research Institute (ICRI), studied the level of salt intake at the population level in a large sample of adults aged >18 years. To the best of our knowledge, there is no other previous population-based study from the Eastern Mediterranean region (EMR) in this regard. Using the methodology of 24-h urine collection, the current study aimed to assess the trend of average salt intake in Iranian adults during 1998–2013 and examine the relationship between Na and K urinary excretion with BP.

Methods

Design and participants

These cross-sectional studies were carried out in healthy adults aged >18 years in Isfahan city, Iran, in 1998, 2001, 2007 and 2013. Participants were selected using multi-stage cluster random sampling method in order to represent the total Isfahan city population [15,17]. After informing the participants, one adult person aged >18 was selected from each household. In this regard, 825, 295, 810 and 1384 healthy individuals were enrolled in 1998, 2001, 2007 and 2013, respectively. People with diabetes insipidus, renal insufficiency, a special dietary regimen, fasting or menstruating on the day of sampling, using diuretics, using oral contraceptives or pregnancy and having excessive sweating during the unusually hot day or unusual physical activity day were excluded. For the present study, we also excluded participants who had incomplete 24-h urine collection [15,18,19]. A total of 564, 157, 509 and 837 adults aged over 18 years were eligible and scheduled for the analysis. The study was approved by the ICRI (a WHO collaborative center) ethics committee. Written informed consents were obtained from all participants.

Data collection

Trained health professionals carried out detailed interviews at study baseline to obtain information about participants' socioeconomic status, including education and occupation, demographic characteristics and smoking status. Physical activity was assessed by means of the International Physical Activity Questionnaire [20].

Measurements

The trained health professionals measured standing height without shoes and recorded it to the nearest 0.5 cm. Body weight was measured with subjects wearing light clothes, without shoes and recorded it to the nearest 0.5 kg. Body mass index (BMI) was calculated as weight divided by height squared (kg/m^2). While subjects were standing, waist circumference (WC) was measured at a level midway between the lower rib margin and iliac crest with the tape all around the body in horizontal position. Hip circumference was also measured at the point yielding the maximum circumference over the buttocks using a non-elastic meter.

Blood pressure was measured manually, by a trained operator, using a mercury sphygmomanometer according to a standard protocol [21], twice in each arm, in sitting position after 5 min of rest. The first Korotkoff sound was recorded as the systolic blood pressure and the disappearance of the sounds (V phase) was considered as the diastolic blood pressure. For the present analysis, we use the mean BP from the arm with the highest value [21].

Urine collection

The urine samples were collected from 7 am to 7 am the next day (after excluding the first sample of the first day) and were poured in a sterile plastic container labeled with the participants' ID and a special code. In cases with urine volume less than 500 mL or its lack of appropriate collection, the samples were excluded from the analysis. If a person was unable to refer for delivery of urine samples for any reason, we referred to his or her home and collected the samples. Fasting venous blood samples were taken to measure serum biochemical indices including, blood glucose, serum albumin level, and lipid profile. In order to obtain the whole 24-h urinary Na (24-hUNa) excretion, we multiplied Na concentration by the urine excretion volume in liters. The measurements of urinary Na, potassium (K) and chloride concentrations were examined by emission flame photometry, and creatinine (Cr) by the Jaffe method (Technical SMA 12–60) [22] in all 24-h urine and spot samples. The incompleteness of 24-h urine samples was evaluated through the following criteria: less than 500 mL of 24-h urine volume measured by a technician; more than one missed voiding and collection of ≥20-h or 24-h urine creatinine (24-hUCr) <20 mg/dL per kg body weight in men and <15 mg/mL per kg body weight in women aged < 50 years and 24-hUCr <10 mg/dL per kg body weight in men and <7.5 mg/mL per kg body weight for men and women aged ≥50 years [18,23].

Salt reduction activities during the period of study

Salt reduction activities were conducted from 2002 to 2007 through the interventional activities of Isfahan Healthy Heart Program (IHHP). IHHP was a long-term community-based interventional program for health promotion through the reduction of CVD risk factors, and hence CVD and its induced morbidity and mortality. The program was carried out in two interventional (Isfahan and Najaf-Abad) and one reference (Arak) cities [17]. One of the main objectives of IHHP was to improve health behavior, such as dietary behaviour of the general population. Details of IHHP study was presented in former publication [24].

Key strategies for the interventional activities included public education through mass media, intersectional cooperation and collaboration, professional education and involvement, marketing and organizational development, legislation and coordination, policy development, as well as research and evaluation [25].

It should be noted that all the educations provided by the IHHP were focused on using less saturated and trans fats, sugar and salt (especially in bread and industrial food products and focused on removing salt shakers from restaurant tables and making sandwiches with less salty cucumber), using more fruit and vegetables, and were mainly conducted through the Islamic Republic of Iran Broadcasting (IRIB), schools, kindergartens, industries, offices, welfare centers and hospitals. The other salt reduction activities in IHHP included holding continuous education courses on nutrition for all physicians in Isfahan province by the collaboration of the Continuous Medical Education (CME) Development Center of Isfahan University of Medical Sciences, prohibiting the consumption of unhealthy high-salt snacks and fast foods at schools and banning the advertisement of unhealthy foods on the IRIB.

Some food industries produced low-salt products. However, some of these actions could not persist due to the inconsistencies, economic problem, consumer taste and undefined marketing strategies. Several ongoing correspondences began reducing the use of salt and preservatives in food industries. Moreover, from 2005 during the implementation of the IHHP, there was an increase in the food labels showing the product's salt content, and

Table 1 Characteristics of the study population.

	1998 n = 564	2001 n = 157	2007 n = 509	2013 n = 837	P-value[d]
Men n (%)	183 (32.4)	51 (32.5)	218 (42.8)	402 (48.0)	<0.001
Age (yr)	40.16 ± 13.45	40.35 ± 15.67	37.5 ± 13.06	38.69 ± 11.19	0.003
Age group n (%)					<0.001
18–30	171 (31.1)	52 (33.1)	195 (38.3)	221 (26.4)	
31–55	274 (49.8)	71 (45.2)	247 (48.5)	535 (63.8)	
55≤	105 (19.1)	34 (21.7)	67 (13.2)	82 (9.8)	
BMI[a] (kg/m^2)	24.91 ± 4.36	24.36 ± 4.59	25.3 ± 4.31	26.13 ± 4.07	<0.001
Overweight & obesity n(%)					<0.001
18–25	289 (53.0)	90 (57.3)	245 (48.1)	339 (40.7)	
25–30	193 (35.4)	50 (31.8)	204 (40.1)	344 (41.3)	
>30	63 (11.6)	17 (10.8)	60 (11.8)	149 (17.9)	
Current smoker (%)	27 (4.9)	15 (9.9)	50 (10.0)	33 (11.1)	0.006
Education (%)					
Illiterate & primary school	267 (48.6)	60 (40.3)	123 (24.2)	11 (13.2)	
Middle & high school	228 (41.5)	67 (40.5)	267 (52.5)	511 (61)	<0.001
College & university	54 (9.8)	22 (14.8)	119 (23.4)	216 (25.8)	
Occupation n (%):					
Manual	161 (29.8)	34 (21.7)	190 (37.3)	364 (43.4)	
Sedentary	19 (3.5)	3 (1.9)	38 (7.5)	76 (9.1)	<0.001
Housewife	326 (60.3)	103 (65.6)	249 (48.9)	347 (41.4)	
Retired	35 (6.5)	17 (10.8)	32 (6.3)	51 (6.1)	
SBP[b] (mmHg)	117.41 ± 9.17	113.66 ± 11.28	103.30 ± 11.17	111.50 ± 10.31	<0.001
DBP[c] (mmHg)	74.98 ± 7.41	72.42 ± 9.03	68.63 ± 8.25	70.54 ± 8.16	<0.001
Pre-hypertension	102 (18.6)	23 (14.9)	52 (10.2)	195 (23.4)	<0.001

[a] BMI: Body mass index.
[b] SBP: Systolic blood pressure.
[c] DBP: Diastolic blood pressure.
[d] ANOVA test was done for continuous variable and Chi-square for categorical one.

later on a provincial level or on a ministry level with authorities at the Ministry of Health, including the Nutrition Improvement Office and the Food and Drug Administration.

Statistical analysis

All statistical analyses were done when the assumptions were checked. Comparison of the continuous variables during the years were performed by ANOVA and Kruskal–Wallis in parametric and non-parametric variables, respectively. Distribution of individuals in terms of categorical variables was compared using the Chi-square test. Trend of mean salt intake were calculated between 1998 and 2013 and compared by ANOVA test. Using multiple logistic regression, we evaluated the relationship between UNa, UK and UNa/UK and prevalence of pre-hypertension in crude and 3 adjusted models. In model 1 we adjusted for age (years) and gender (men/women); model 2 was additionally adjusted for education (illiterate & primary school/middle & high school/college & university), occupation (manual/sedentary/housewife/retired) and smoking (current smoker/nonsmoker); model 3 was additionally adjusted for BMI. We considered 2-tailed P values of less than 0.05 to be statistically significant. Analyses were conducted using SPSS statistical software version 19.0 for windows (SPSS Inc., Chicago, USA).

Results

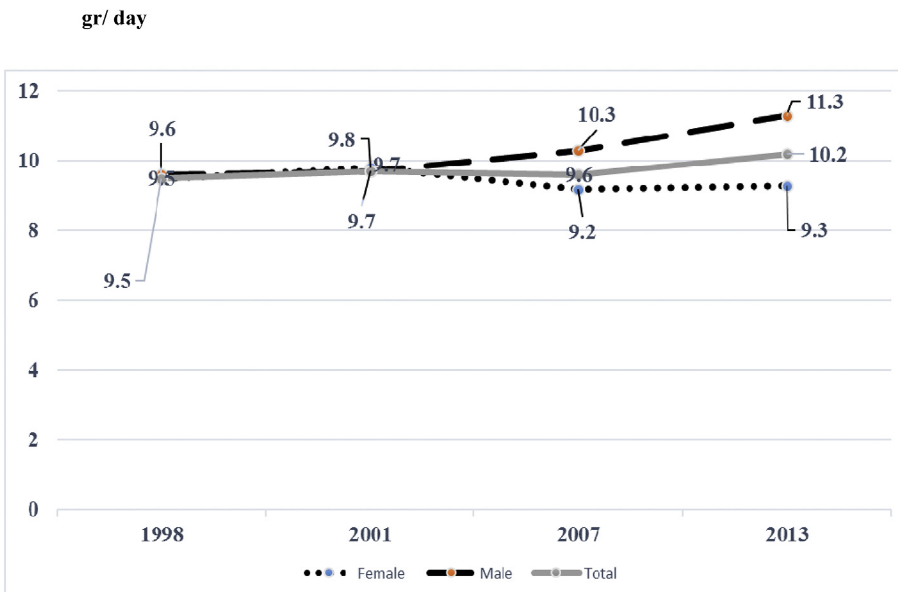
From a total of 825, 295, 810 and 1384 healthy individuals enrolled to the study, we excluded 261, 138, 301 and 547 because of incomplete urine collection samples. Thus, a total of 564, 157, 509 and 837 adults aged over 18 years were included in 1998, 2004, 2007 and 2013, respectively. Table 1 shows basic characteristics of the study population including mean age, BMI, SBP and DBP and frequency of participants based on gender, age group, education level, occupation status, current smoking, overweight and obesity based on year of study. The mean of 24-hUNa was from 156.4 ± 61.2 mmol/day to 167.5 ± 44.0 mmol/day in women and from 162.6 ± 19.3 mmol/day to 193.5 ± 73.7 mmol/day in men during the years. The range of 24-hUK was 45.7 ± 27.0–60.8 ± 31.5 mmol/day and 44.7 ± 24.1–68.0 ± 37.1 mmol/day in women and men, respectively (Table 2). The trend of salt intake was 9.5, 9.7, 9.6 and 10.2 g/day in total population ($P < 0.001$). The trend of salt intake was significantly increasing in men, but not in women (Fig. 1). Salt intake was more than WHO recommended intakes in 96%, 98%, 95% and 94% of participants in 1998, 2001, 2004 and 2013, respectively.

Table 3 shows that after adjustment for all potential confounders, the risk of pre-hypertension was 21%and 18% significantly greater in highest quartiles of UNa/UK, compared with lowest, in 2001 and 2013, respectively [OR (95% CI): 1.21 (1.03–1.64)) and 1.18 (1.02–1.38), respectively]).

Table 2 The mean value of 24-h urinary sodium, potassium and creatinine excretion by gender and year of study.

	1998		2001		2007		2013	
	Men n = 183	Women n = 381	Men n = 51	Women n = 106	Men n = 218	Women n = 291	Men n = 402	Women n = 435
UNa[a] (mmol/day)[d]	163.47 ± 16.09	162.56 ± 19.31	165.94 ± 40.85	167.54 ± 44.01	175.4 ± 71.46	156.41 ± 61.22	193.54 ± 73.71	158.3 ± 65.68
UK[b] (mmol/day)[d]	44.75 ± 24.15	45.72 ± 27.02	51.15 ± 15.68	54.12 ± 19.15	68.05 ± 37.13	60.81 ± 31.51	59.97 ± 29.87	52.44 ± 26.38
UNa/UK[e]	4.92 ± 3.11	5.01 ± 3.48	3.44 ± 1.06	3.38 ± 1.15	2.98 ± 1.35	2.93 ± 1.36	3.79 ± 2.12	3.46 ± 1.80
Volume (ml/day)[d]	1568.8 ± 411.72	1475.06 ± 455.60	1568.6 ± 532.53	1445.28 ± 456.72	1525.8 ± 433.52	1469.63 ± 439.39	1599.3 ± 560.85	1419.9 ± 557.89
UCr[c] (mmol/day)[d]	1551.22 ± 493.58	1439.70 ± 482.66	1453.25 ± 370.38	1237.16 ± 371.87	1790.84 ± 389.15	1217.22 ± 370.44	1939.03 ± 595.49	1317.6 ± 414.98

[a] UNa: Urine sodium.
[b] UK: Urine potassium.
[c] UCr: Urine creatinine.
[d] P value for trend was less than 0.001 for both genders based on ANOVA test.
[e] P value for trend was less than 0.001 for both genders based on Kruskal–Wallis test.



	1998	2001	2007	2013	P-value
Women	9.5	9.8	9.2	9.3	0.181
Men	9.6	9.7	10.3	11.3	<0.001
Total	9.5	9.7	9.6	10.2	<0.001

Figure 1 Trend of salt intake among adult population of Isfahan city, Iran 1998–2013.

Table 3 Odds ratio (95% confidence interval) of pre-hypertension according to quartiles of sodium to potassium ratio.

	Quartiles	1998 n = 564	2001 n = 157	2007 n = 509	2013 n = 837
		OR (95% CI)[a]	OR (95% CI)	OR (95% CI)	OR (95%) CI
Pre-hypertension n (%)		102 (18.6)	23 (14.9)	52 (10.2)	195 (23.4)
Crude model	1	1	1	1	1
	2	0.78 (0.41–1.47)	1.33 (0.53–2.17)	1.21 (0.50–2.91)	0.99 (0.48–1.55)
	3	0.85 (0.46–1.59)	1.64 (0.62–2.70)	1.32 (0.56–3.14)	1.19 (0.59–1.96)
	4	1.19 (0.66–2.14)	1.86 (0.65–3.03)	1.79 (0.79–3.08)	1.20 (0.76–2.03)
Model 1[b]	1	1	1	1	1
	2	0.79 (0.42–1.51)	1.13 (0.55–1.70)	1.30 (0.52–3.21)	1.04 (0.49–1.81)
	3	0.81 (0.43–1.53)	1.36 (0.60–1.95)	1.51 (0.61–3.71)	1.35 (0.66–2.49)
	4	1.13 (0.62–2.06)	1.47 (0.70–2.21)	1.43 (1.02–1.86)	1.27 (0.93–1.68)
Model 2[c]	1	1	1	1	1
	2	0.86 (0.45–1.67)	1.03 (0.61–1.51)	1.25 (0.60–1.91)	1.15 (0.75–1.64)
	3	0.87 (0.45–1.67)	1.28 (0.69–1.88)	1.41 (0.77–2.04)	1.33 (0.83–1.07)
	4	1.24 (0.67–2.30)	1.49 (0.75–2.24)	1.45 (0.94–2.11)	1.24 (0.80–1.55)
Model 3[d]	1	1	1	1	1
	2	0.96 (0.49–1.88)	1.20 (0.86–1.63)	1.25 (0.92–1.59)	1.21 (0.95–1.62)
	3	0.99 (0.50–1.94)	1.25 (0.95–1.54)	1.30 (0.98–1.66)	1.27 (1.03–1.56)
	4	1.43 (0.76–2.71)	1.21 (1.03–1.64)	1.23 (0.96–1.54)	1.18 (1.02–1.38)

[a] OR (95% CI): Odds ratio (95% confidence interval).
[b] Adjusted by age (years) and gender (men/women).
[c] Additionally adjusted by education (illiterate & primary school/middle & high school/college & university), occupation (manual/sedentary/housewife/retired) and smoking (current smoker/nonsmoker).
[d] Additionally adjusted by body mass index.

Discussion

Using the most valid method of salt intake assessment which is the 24-h urine collection, the current study aimed to assess the trend of average salt intake in Iranian adults during from 1998 to 2013. Mean salt intake had an increasing trend from 1998 to 2011 in both genders, however the salt intake decreased from 2001 to 2007 in women and total population, and again increased in both genders. It was higher in men than women during the period of time studied. Reduced salt intake is the most cost-effective strategy that can decrease the burden of NCDs, especially CVDs, to a good extent [12]. There has been no study measuring 24-hUNa excretion in a nationally representative Iranian sample, however, some studies with small sample size were performed to estimate salt intake in different cities [26]. It has a general consensus that the average salt intake of our population is above the recommendations. Although, single 24-h urine collections for assessing average population group intake van be appropriate, it should be acknowledged that it is not sufficient to assess individual salt intake and the long-term effects of salt consumption on vital outcomes [27,28].

Our findings were in line with most of the countries around the world. Salt intake was 10.1 g/day among adults worldwide in 2010. Moreover, similar to our results, the salt intake was globally higher in men than women (10.3 vs 9.4 g/day, respectively) [14]. The salt intake was the highest and higher than 12 g/day in Asian countries. It was estimated 10 g/day in Middle East/North Africa region (MENA) and ranged between 7.8 g/day in Lebanon and 13.4 g/day in Bahrain among MENA region. However, it was less in high income USA, European and Australian countries [29].

More than 95% of our participants consumed higher than WHO recommendation. It was higher than urban resident of South African and Australian women, but less than Chinese, European and Americans [30–32]. Globally, 99% of population worldwide consumed more than WHO recommendation and it was more than two folds in about 45% of world's adult population [29]. Consistent to our findings global trend of salt intake increased from 10 to 10.4 g/day in men and 9.1–9.4 g/day in women during 1990–2010 [29]. However, some countries including UK, Finland, Australia, New Zealand and Canada implemented salt reduction programs, and UK had the best results in terms of reduced salt intake by approximately 10%; from 9.5 g/day to 8.6 g/day between 2000 and 2008 [33].

Our findings showed a reduction in mean salt intake from 2001 to 2007 in women and overall population that might be due to IHHP interventional activities. However, it had increased in men and also women after that. Similarly, in France, implementing some actions to reduce the salt content of foods in 2000 led to salt intake reduction from 8.1 to 7.7 g/day in the overall adult population. Finland commenced efforts to reduce salt in 1978 and by 2002 had demonstrated a 3 g reduction in average population salt intake (from 12 to 9 g/person per day) [33].

There was a significant positive association between UNa/UK ratio which are proxy for high salt diet and pre-hypertension in the fully adjusted model in 2007 and 2013. In agreement to our results, some studies indicated that the ratio of UNa/UK had a more strong association with the risk of pre-hypertensive occurrence than only UNa or UK levels [34–37].

Systematic review by Perez et al. of RCTs revealed that Na/K ratio had stronger effect on blood pressure outcomes to either Na or K alone in hypertensive populations. However, its effect remained uncertain in normotensive populations [37]In addition, a large scale observational study of INTERSALT in 52 communities [38] reported increasing BP with greater level of UNa/UK. The Trials of Hypertension Prevention (TOHP) Follow-up Study concluded that higher Na/K level were associated with increased CVD risk among pre-hypertensive population [39].

The potential mechanism of adverse effect of Na intake on raising BP may be due to releasing sympathetic systems and constrain the nitric oxide production by consuming high dietary Na [40]. Although there is no clear reason for the reduction effect of K intake on BP, it may be occurred by improving nitric oxide synthesis through intracellular K enhancement [40]. However, different subjects with diverse polymorphisms in some functionally related genes may have various feedbacks to K intake [41].

The use of the most valid method of 24-h urine collection for the assessment of average of population salt intake is one of the main strengths of our study. To the best of our knowledge, this was the first examining the trend of salt intake using data of four surveys on independent randomly samples with relatively large sample size in Iran and the Middle East. Single 24-h urine sample could not accurately assess individual salt intake since day to day variation in UNa excretion occurs, being this a potential limitation of our study. Owing to the cross-sectional design of current study, we could not causality effect of Na and K level.

Conclusions

This population-based four cross-sectional studies indicated the mean salt intake was about two time the WHO recommendations in our population and it was higher in men than women. Specially the trend increased in men between 1998 and 2013, but it had reduction slope in women and totally between 2001 and 2007 when the salt reduction of IHHP implemented. UNa and UNa/K ratio was significantly associated with pre-hypertension occurrence. Subsequently, it is essential to the implement a salt reduction program in Iranian population. A longitudinal study at national level using a representative sample of individuals is warranted to examine the real trend of average salt intake in the future. It is suggested to perform well-designed randomized clinical trials with multiple 24-h urine collections in non-consecutive days to investigate the causality effects of dietary Na and K intake on BP.

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