Urinary sodium to potassium ratio: A simple and useful indicator of diet quality in population-based studies

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DOI: 10.21203/rs.2.12332/v1

SUBJECT AREAS Nutrition & Dietetics

KEYWORDS Sodium, Potassium, Urine, Dietary pattern
Abstract

Background

Urinary sodium (Na) and potassium (K) are related to dietary intakes of Na and K, and well-known risk factors of hypertension and cardiovascular events. This study aimed to evaluate the associations between urinary Na/K ratio and different dietary patterns.

Methods

We recruited 1864 adult men and women (aged 18-93 years), participated in the sixth examination of Tehran Lipid and Glucose Study. Fasting spot urine samples were collected and concentrations of Na and K were determined. The principle component analysis (PCA) was conducted to drive major dietary patterns among population. Mediterranean dietary pattern score, as well as DASH score, were calculated. Linear regression models adjusted for potential confounding variables were used to assess associations between dietary patterns scores and urinary Na/K ratio.

Results

Mean age of participants was 43.7±13.9 years, and 47% were men. Mean urinary Na and K concentrations were 139±41.0 and 57.9±18.6 mmol/L, respectively. Mean urinary Na/K was 2.40±0.07. A significant positive association was found between Western dietary pattern and urinary Na/K ratio (β=0.06; 95% CI= 0.01, 0.16). Traditional dietary pattern derived from usual dietary intakes of Iranian adults, as well as Mediterranean and DASH dietary pattern scores were inversely associated to urinary Na/K ratio (β= -0.14; 95% CI= -0.24, -0.11, β=-0.07; 95% CI= -0.09, -0.01, β=-0.12; 95% CI= -0.05, -0.02, respectively).
Conclusions

Urinary Na/K ratio may suggest as a simple, inexpensive and helpful method to monitor and improve diet quality in population-based studies.

Background

Excessive dietary sodium (Na) and insufficient potassium (K) intakes, are well-known risk factors for hypertension and cardiovascular events (1, 2). There are two major methods to assess Na and K intakes, 24-h recall to remember the food items consumed and then calculation of Na and K intakes, and calculation of urinary excretion of Na and K, which is a more accurate method (3). Since more than 90% of dietary Na and K are excreted in urine, high excretion of Na and low excretion of K and elevated urinary Na/K ratio are associated with excessive Na and insufficient K intakes, therefore it could be used as an indicator for modifying the diet (4). Evidence suggests that compared to dietary Na or K intakes, urinary Na/K ratio has higher association with blood pressure and cardiovascular disease (CVD) risk (5-8), and can be considered as a useful intervention target for hypertensive patients (9). Despite relation between urinary Na/K ratio and dietary intakes of Na and K, the association between urinary Na/K ratio, as an indicator of diet quality, and different dietary patterns has not completely understood. Few observational studies have investigated the association between urinary Na/K ratio and dietary patterns, healthy dietary patterns rich in nuts, seeds, fruit and fish, as well as Japanese dietary pattern were associated with lower urinary Na/K (10, 11). On the other hand, a dietary pattern rich in snacks, fast food, and soft drinks, and Noodle pattern were positively associated with urinary Na/K (10, 12).

In the present study, we aimed to evaluate the association between four dietary
patterns (traditional and Western dietary patterns, Mediterranean dietary pattern, Dietary Approach to Stop Hypertension (DASH)) and urinary Na/K ratio (as an indicator of diet quality) among an Asian adult population.

Methods

Study population

The present study was conducted within the framework of Tehran Lipid and Glucose Study (TLGS), a prospective study on a representative sample of residents from district 13 of Tehran, to investigate and prevent non-communicable diseases (NCD) (13). TLGS is an ongoing community-based study that started with 15,005 individuals aged ≥3 years in 1999, and data collection is repeated every 3 years to assess any changes of NCD risk (14). For the current analysis, we recruited 1864 adult men and women (age ≥19 years), with complete data on spot urinary values (Na, K and creatinine), demographics, anthropometrics, biochemical measurements and dietary intakes in the sixth TLGS examination (2014-2017). Participants who had under-reported or over-reported energy intake (<800 kcal/d or >4200 kcal/d, respectively) were excluded from the final analysis.

Anthropometric and demographic measures

Weight was measured by digital scales (Seca, Hamburg, Germany), height and waist circumference were measured by a tape meter, and they were reported to the nearest 100 g and 0.5 cm, respectively. Waist circumference was measured at the level of the umbilicus. Subjects were minimally clothed and without shoes for anthropometric measurements. Body mass index (BMI) was calculated as weight (kg) divided by height in square (m²).

Systolic (SBP) and diastolic (DBP) blood pressures were measured using a standard
mercury sphygmomanometer calibrated by the Iranian Institute of Standards and Industrial Researches (15). Blood pressure was measured on the right arm of the participants in a sitting position for two times, with at least a 30-second interval between two measurements, and a 15-minute rest before measurement. Mean of the two measurements was considered as the participant's blood pressure.

**Biochemical measures**

Both blood and spot urine samples were drawn between 7:00 and 9:00 AM following overnight fasting. Urinary concentrations of Na and K were measured using flame photometry (Screen lyte, Hospitex Diagnostics, Florence, Italy). Both intra- and inter-assay coefficients of variations (CVs) were ≤ 2.8% for Na, and ≤ 4.8% for K. Fasting serum glucose (FSG) and triglycerides (TG) levels were determined by the enzymatic colorimetric method, using glucose oxidase and glycerol phosphate oxidase, respectively. High-density lipoprotein cholesterol (HDL-C) was measured by a homogenous method (HDLC Immuno FS). Blood analysis were done using Pars Azmoon kits (Pars Azmoon Inc., Tehran, Iran) and a Selectra 2 auto-analyzer (Vital Scientific, Spankeren, The Netherlands) at the research laboratory of the TLGS. Both inter- and intra-assay coefficients of variations (CVs) were ≤ 5%.

**Dietary assessment**

Dietary assessment was done using a validated 147-item food frequency questionnaire (FFQ). The intake frequency of each typical food item in previous year was asked on a daily, weekly, or monthly basis in household measures, and then converted to grams (16). Since the Iranian Food Composition Table (FCT) has limited data on nutrient content of raw foods and beverages, the US Department of Agriculture’s (USDA) Food Composition Table was used to analyze foods and beverages for their energy and nutrient contents. For the traditional Iranian foods
not founded in the USDA table, Iranian FCT was used as an alternative. The validity and reliability of the FFQ have previously been reported (17).

**Ethical Consideration**

Written informed consents were obtained from all participants. The study protocol was approved by the ethics research council of the Research Institute for Endocrine Science, Shahid Beheshti University of Medical Science.

**Statistical analyses**

Differences between general characteristics of participants were compared across tertiles of urinary Na/K ratio, using one-way ANOVA or Chi-square tests, for dichotomous and continues variables, respectively. The principle component analysis (PCA) with varimax rotation was conducted to derive dietary patterns, based on 18 predefined food groups (whole grains, refined grains, starched vegetables, non-starched vegetables, fruits, beans, high fat dairy, low fat dairy, red meat, poultry, vegetable oil, hydrogenated and animal fat, fast foods, salty snacks, sweet snacks, sweetened beverages, nuts and seeds, tea and coffee). We considered eigenvalues >1, the scree plot and the interpretability of the patterns, and 2 factors were obtained. Although all food groups contributed to the pattern score calculation, food groups with an absolute component loading ≥0.30 were selected to describe the pattern. The Kaiser-Mayer-Olkin statistic, measure of sampling adequacy, was 0.67 (values >0.6 indicate the usefulness of cluster analysis using our data), and the P value for Bartlett’s test of sphericity was <0.001 supporting the use of cluster analysis as an appropriate procedure. Factor scores were calculated using sum of the intake of the standardized food groups weighted by their respective factor loadings on each pattern.

*Calculation of Mediterranean and DASH dietary scores*
To assess the Mediterranean dietary pattern score, we used an index variable that was composed of the 8 Mediterranean food groups. If consumption of each vegetables, fruits, legumes, nuts, whole grains, fish and MUFA/SAFA was above the median consumption, we assigned score 1 and if their consumption was below the median, we assigned score 0. For total red meat, if the subjects consumed more than median, we assigned score 0 and if they consumed lower than median, score 1 was assigned. The Mediterranean dietary pattern score was obtained by summing all group scores (18).

To represent the DASH score, we used an index based on 8 components: High intakes of fruits, vegetables, nuts and legumes, low fat dairy products, and whole grains and low intakes of sodium, sweetened beverages, and red and processed meats. For each of eight components, individuals were classified into five categories according to their intake ranking. For healthy components (fruits, vegetables, nuts and legumes, low fat dairy products, and whole grains) quintile 1 assigned point 1 and quintile 5 assigned point 5. In contrast, for low recommended components (sodium, sweetened beverages, and red and processed meats) quintile 1 assigned point 5 and quintile 5 assigned point 1. The overall DASH score was obtained from the sum of 8 component scores, and ranged from 8 to 40 (19).

To assess potential association of dietary patterns scores with urinary Na/K ratio, we used linear regression models. Potential confounding variables, including age, sex, BMI, WC, SBP and DBP were entered to univariate models to determine confounders. Variables with $P_E < 0.2$ in the univariate analyses were selected as confounders. Finally, confounders adjusted in models included sex (male or female), age (year), BMI ($kg/m^2$), and total energy intake (kcal/d). All statistical analyses
were conducted using Statistical Package for Social Science (version 20; IBM Corp., Armonk, NY, USA) and $P$-value $< 0.05$ was considered significant.

Results

The current study was conducted on 1864 adult participants, aged $\geq 19$ years. Mean age of participants was $43.7 \pm 13.9$ years, and 47% of the participants were men. Mean calorie intake of the participants was $2241 \pm 680$ kcal/day and mean BMI was $27.7 \pm 5.10$ kg/m$^2$. Mean dietary intake of Na and K were $3498 \pm 1681$ and $4415 \pm 1697$ mg/d, respectively. Mean urinary Na and K concentrations were $139 \pm 41.0$ and $57.9 \pm 18.6$ mmol/L, respectively. Mean urinary Na/K ratio was $2.40 \pm 0.07$. Clinical characteristics of the participants across tertiles of Na/K ratio are shown in Table 1. Dietary intakes of the participants across tertiles of Na/K ratio are presented in Table 2. Participants in the highest tertile of urinary Na/K ratio, compared to those in the first tertile, had significantly lower consumption of fruits (370 vs. 440 g/d), vegetables (282 vs. 321 g/d), low fat dairy (228 vs. 261 g/d), nuts and seeds (12.04 vs. 14.7 g/d). Dietary intakes of refined grains and hydrogenated and animal fats were significantly higher in the last tertile of urinary Na/K ratio, compared to the first tertile (284 vs. 247 g/d and 17.34 vs. 14.99 g/d, respectively). There was no significant difference in dietary intake of other food groups across tertiles of urinary Na/K ratio.

Principal component analysis identified two major dietary patterns, traditional and Western dietary patterns. Traditional pattern was characterized by higher loads of starchy and non-starchy vegetables, sweet and salty snacks, sweetened beverages, fruits, nuts and seeds, poultry, high fat dairy, red meat, and beans. Western pattern had higher loads of sweetened beverages, high fat dairy, refined grains, fast foods,
hydrogenated and animal fats. These patterns explained 21.35 % of the total variance in the dietary intake overall (Table 3).

Mean (±SD) of urinary Na, K and Na/K ratio across tertiles of dietary pattern scores are shown in Table 4. Mean urinary Na concentration, as well as urinary Na/K ratio, were significantly lower in participants in the highest tertiles of traditional dietary pattern, DASH and Mediterranean dietary pattern (P-value for all < 0.05). In contrast, mean urinary Na concentration and Na/K ratio were significantly higher in participants in the highest tertile of Western dietary pattern (P-value < 0.05). There were no significant differences between urinary K concentrations across tertiles of dietary patterns.

Associations between dietary pattern scores and urinary Na/K ratio are shown in Table 5. After adjustment for confounding variables, traditional dietary pattern (β=-0.14; 95% CI= -0.24, -0.11), DASH (β=-0.12; 95% CI= -0.05, -0.02) and Mediterranean dietary pattern (β=-0.07; 95% CI= -0.09, -0.01) were inversely associated with urinary Na/K ratio. In contrast, Western dietary pattern was positively associated to urinary Na/K ratio (β=0.06; 95% CI= 0.01, 0.16).

Discussion

In the current cross-sectional population-based study, we found that traditional dietary patterns with high load of vegetables, fruits, sweet and salty snacks, sweetened beverages, nuts and seeds, poultry, high fat dairy, red meat and beans, as well as DASH and Mediterranean dietary patterns were negatively related to urinary Na/K ratio. Western dietary pattern with higher loads of sweetened beverages, high fat dairy, refined grains, fast foods, hydrogenated and animal fats, was significantly associated with higher urinary Na/K ratio. To our knowledge, this is
the first study to investigate the associations between urinary Na/K, as reliable indicator of diet quality and Mediterranean, DASH, healthy and Western dietary patterns.

The present study showed a significant inverse association between urinary Na/K ratio and adherence to Mediterranean dietary pattern and DASH. Mediterranean diet promotes consumption of whole grains, legumes, fruits, vegetables, nuts, fish and olive oil, wine in moderation, and a moderate intake of meat, dairy products, processed foods and sweets (20). Subjects with a higher Mediterranean dietary pattern score had a better nutrient profile, with lower sodium and higher potassium intakes (21). DASH is a healthful dietary pattern, rich in vegetables, fruits, nuts and seeds, whole grains and low-fat dairy products, provides high amount of fiber, protein, magnesium, calcium, and potassium, and restricted amount of sodium to about 1500 mg/day (22, 23). Mediterranean dietary pattern and DASH are two ways of eating to protect from hypertension and non-communicable diseases including CVD, type 2 diabetes, stroke and obesity, may improve health status and reduce total lifetime costs (23-26). Our present results were in line with those of previous studies that investigated the association between Japanese dietary patterns and urinary Na and K concentration, in which the patterns with high loadings for fish and vegetables were positively associated with high urinary K concentration (10).

Furthermore results of the current study provide more evidence on previous studies reporting significant inverse association between “nuts, seeds, fruits and fish” dietary pattern and urinary Na/K ratio (11).

Additionally, we assessed the potential associations of common dietary patterns of Iranian adults with urinary Na/K ratio. In our population, Western dietary pattern was associated with higher Na/K and traditional dietary pattern was associated with
lower Na/K ratio. Similarly, Noodle pattern (10), and “snacks, fast food, soft drinks” pattern (12) were positively associated with urinary Na concentration in previous studies.

Mean urinary Na/K ratio in our population was 2.40. The World Health Organization (WHO) guidelines have suggested Na and K intakes would yield a Na/K ratio of approximately 1.00 (27, 28). The Trials of Hypertension Prevention (TOHP), reported that urinary Na/K ratio less than 2.00 is associated to a lower risk of CVD (7). Higher urinary Na/K ratio was associated with a greater risk of hypertension and CVD (16), or chronic kidney disease progression (17). Mean 24-h urinary Na/K ratios ranged from 0.01 in Brazil to 7.58 in China, mean Na/K ratios in Asian and Western populations were approximately 5 and 3, respectively (5, 29).

It is notable that measurement of Na and K in 24 h urine is the gold standard method to estimating their intakes, but it is difficult to collect 24 h urine without any loss of urine and it is too inconvenient for people. There is a report that the rate of unsuccessful collection of 24 h urine samples is about 40% (30). Furthermore, particular attention has focused on estimating the Na and K intake using the ‘spot’ urine sample (31). The collecting time of the spot urine has no restriction, although the 24-h urinary Na and K excretion are affected by circadian rhythms (32, 33). There are a number of confirmed formulas to estimate 24-h urine Na/K ratio, using spot urine values of Na and K, in some cases with use of creatinine values (30, 31). Pearson correlation coefficients of 24-h urinary Na/K ratio and spot urine Na/K ratio assessed and reported from $r = 0.88$ to $0.96$ in subgroups categorized by sex, age and across Western/Asian populations. Moreover, correlations were $r = 0.96$ and $r = 0.69$ in analyses across populations and individuals, respectively (29). It can be concluded that spot urine Na/K ratio could
be a useful, low-burden alternative method to 24-h urine estimation in populations, for comparing different populations, as well as indicating annual trends of a particular population, but not suitable for estimating individual’s 24-h urine excretions (29, 30).

The strengths of the present study include its relatively large sample size, use of a validated comprehensive FFQ to assess dietary intakes, and evaluating the association between four dietary patterns and Na/K ratio, simultaneously. Although spot urine sample is a simple, low-burden method to estimate 24-h urine concentrations, it has some limitations in estimating 24-h urine Na/K concentration, due to the potential differences in urinary excretions at different hours one day, and differences in 24-h creatinine excretion.

Conclusions

We found a significant positive association between Western dietary pattern and urinary Na/K ratio. Also, traditional dietary pattern derived from usual dietary intakes of Iranian adults, as well as Mediterranean dietary pattern and DASH scores were inversely associated to urinary Na/K ratio. Further studies are warranted to confirm our findings, so that we can benefit from this ratio in our researches and in the community level, to monitor and improve quality of diets.

List of Abbreviations

TLGS; Tehran Lipid and Glucose Study

FFQ; Food Frequency Questionnaire

BMI; Body Mass Index

SBP; Systolic Blood Pressure
DBP; Diastolic Blood Pressure
FPG; Fasting Plasma Glucose
HDL; High Density Lipoprotein
TG; Triglyceride
CI; Confidence Interval

Declarations

Ethics approval and consent to participate: Written informed consents were obtained from all participants, and the study protocol was approved by the ethics research council of the Research Institute for Endocrine Science, Shahid Beheshti University of Medical Science in Tehran.
Consent for publication: Not Applicable
Availability of data and material: Not Applicable
Competing interests: The authors declare that they have no competing interests
Funding: This work was not supported by any funding agency.
Authors' contributions: Parvin Mirmiran designed the study. Zahra Gaeini, Zahra Bahadoran and Asghar Ghasemi analyzed the data from TLGS population, Zahra Gaeini, Parvin Mirmiran and Maryam Tohidi wrote the manuscript, Fereidoun Azizi corrected the manuscript. All authors read and approved the final manuscript.
Acknowledgements: The authors would like to express their appreciation to the participants in the Tehran Lipid and Glucose Study for their cooperation, and the staff of the Research Institute for Endocrine Science, TLGS Unit. The authors wish to acknowledgment Ms. Niloofar Shiva for critical editing of English grammar and syntax of the manuscript.
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Tables

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