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Urinary and dietary sodium to potassium ratio as a useful marker for estimating blood pressure among older women in Indonesian urban coastal areas

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Abstract.
BACKGROUND: Risk factors for hypertension (HT) are age, high sodium (Na) intake, and low potassium (K) intake, as well as the geographical location of a region such us coastal area. Calculation of the sodium-to-potassium (Na/K) ratio was more∼strongly associated with blood pressure (BP) than either Na or K alone. Dietary recalls and urine analyses are the most feasible methods for estimating electrolyte intake.
OBJECTIVE: This study aims to analyze the association between both urinary and dietary (Na/K) ratio and BP among older women residing at urban coastal in Indonesia.
METHODS: The cross-sectional study involved 51 older women aged ≥45 y post menopause in urban coastal dwellers. A single 24-h urine collection and food recall 2 × 24 h were used to assess sodium and potassium intake.
RESULTS: Of the 51 subjects mean age 56.98 ± 5.7 years completed the study, 37.3% of subjects were classified as hypertensive. The mean of urinary and dietary Na/K ratio were 5.28 ± 1.68 and 1.12 ± 0.74 respectively. Urinary Na/K ratio was independently associated with systolic BP (SBP), meanwhile, the association between dietary Na/K ratio and both SBP and diastolic BP (DBP) showed significant correlation only in the unadjusted model.
CONCLUSION: Na/K ratio is a useful marker for estimating SBP and assessing populations at high risk for HT. The slightly low Na and substantially low K intake might cause the Na/K ratio become high enough to induce HT. Since the prevalence of HT is high enough, studies in this field may provide clues for the further understanding of its causes and get effectively ways to decrease Na/K ratio in urban coastal dwellers.

Keywords: Sodium, potassium, blood pressure, urban coastal, hypertension

1. Introduction

A raised blood pressure (BP) is the most common and preventable risk factors for cardiovascular disease both in Western and Asian populations; population living in urban areas have the prevalence of hypertension (HT) 2–3 times higher than in rural areas [1, 2]. The prevalence of HT in developing countries was 32.3%, it means about

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1 in 3 adults in thoses area is hypertensive [3]. Reducing the burden disease associated with HT has become as a global public health priority and a major public health challenge [1]. Indonesian National Health Survey 2013 reported that 26.5% of the Indonesian adult population have established HT, furthermore, most of (63.2%) HT cases in society were not yet diagnosed [4].

Risk factors for HT include age, high intake of sodium (Na), and low intake of potassium (K), as well as the geographical location of a region [5–8]. Epidemiological study described that female gender, older age, and HT increase the sensitivity to dietary sodium intervention [9]. The association with older age raises concerns about hormonal problems in elderly, which could increase the risk of HT [9]. Moreover, the INTERSALT (International Study of Electrolyte Excretion and Blood Pressure) study reported stronger associations between Na/K ratio and blood pressure with increasing age [10].

Most populations around the world consume less than the recommended intake of K, unfavorably high Na intakes remain prevalent around the world. High Na and low K together had a pivotal role in the pathogenesis of HT [11]. Population studies have reported significant correlation between Na intake and BP, and so have K intake [8,10]. Furthermore, a systematic review have revealed that the sodium to potassium [Na/K] ratio was more strongly associated with HT and BP than either Na or K alone [12].

Several methods were applied by population studies to assess Na and K intake. Urine analyses and dietary recalls are the most feasible methods for estimating electrolyte intake [12–14]. The measurement of 24-hour urinary Na and K excretion is the 'gold standard' and highly reliable method for obtaining data of these intakes in population since it reflects more than 90% of Na and K intake. On the other hand, dietary method is easier to perform and more convenience thoughtless reliable [15, 16].

Studies on Na and K intake using 24-hour urine collection in the healthy population have been applied by many countries in the worldwide [16], although most studies still applied dietary methods to know sodium and potassium intake in society [17]. Several studies demonstrated that region had a significant interaction with the risk of HT [5, 6, 8, 18]. Moreover, Du et al. reported the interaction between the region of residence and Na/K ratio are significant [18].

Community-dwelling in coastal area has a high risk of HT. The tradition of salting and drying fish to preserve fish by coastal communities was a custom and their occupational every day. The high amount of salt used for salting fish can increase the Na intake in these populations and have an undesirable effect on BP [7, 19, 20]. On the other hand, low K intake in urban dwellers was inverse association with BP [8, 21].

Indonesia is an archipelagic country, with high prevalence of HT [4]. Many communities (about 60% of Indonesian people) reside in coastal region [22]. Measuring sodium and potassium intake by 24-hour urinary method at the urban coastal resident in Indonesia is challenging and have never been done. The analysis of relationship between Na/K ratio and BP often uses only one method. This study aims to analyse the association between Na/K ratio and BP among older women residing at urban coastal in Indonesia, using two methods single urinary 24-h and dietary food recall $2 \times$ 24-hours, and furthermore to assess whether those methods are applicable to identify populations at high risk for HT in this community.

2. Subjects and methods

2.1. Study subjects

Our study assumed that older women related to menopause, so we included healthy old adult women aged $\geq$45 years old and post menopause as participants, although most area use $\geq$60 years to refer to the older population. Since almost of older person in urban coastal in Kenjeran Surabaya (central city of east Java, Indonesia) followed programme of community health care facilitated by government, data was collected on two selected places from five elderly community health care in urban coastal area in Surabaya with cluster random sampling method and subjects recruitment by consecutive sampling. Because of completeness of urine collection, we recruited all respondents in two places (135 respondents following the strict screening stage) and finally, for one year study (2015), fifty-one subjects met the study criteria.

We recruited only female because most of (88%) participants participating actively at community health care in that place were female. Moreover, there was the difficulty of collecting urinary 24 h in men since they generally worked outside the home (mostly as fishermen). Participants were included in the study if they were post-menopause, permanent resident in coastal area for more than 10 years, and willing to collect a 24-hours urine sample. Participants with cognitive impairment (mini mental state examination score <24), kidney dysfunction (creatinine clearance test (<60 mL/min), consuming tobacco and alcohol, and inaccurate urine collection were excluded.

The present study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures were approved by the Ethics Committee of the Faculty of Public Health, Universitas Airlangga, and written informed consent was obtained from all subjects.

2.2. Study measurements

Data collection in this study including structure questionnaire, food recall 2 × 24 hours, anthropometric measurements, a 24-hours single urine sample, and a blood sample was obtained from all subjects. A structured questionnaire was fulfilled by participants. Body weight, height, and BP were measured. At the end of the first visit, all participants were given plastic bottles complete with written and verbal instructions for a single 24-hours urine collection measured. The sample urine was brought by the researcher to ISO 9001 certificated laboratory to be measured of urinary sodium, potassium, and creatinine. Sodium and potassium were analyzed by ion-selective electrodes method which responds relatively specifically to ions both anions and cations [23]. Creatinine determination in biological fluids was carried out by Jaffe's reaction [24]. Participants were also asked to recall their dietary intake over the previous 2 × 24 hours.

2.3. Anthropometric data

Weight and height were measured by a trained investigator using calibrated electronic scale. Weight and height, to calculate Body Mass Index (BMI), were measured without shoes and heavy clothes. All data were collected following norms set out by the WHO. BMI was computed as the ratio of weight (kg) per square height (m^2).

2.4. Physical activity

Physical activity of subjects was obtained by interview and the physical activity point was calculated by multiplication score of intensity, duration, and frequency from the questionnaire. It was categorized below the average if total score was less than 40 point [25].

2.5. Blood pressure

Blood pressure was measured on the right arm of seated participants following a 5 min rest period, using standard calibrated mercury sphygmomanometers with regular adult cuffs by trained nurse. Three times measurements were obtained with participants and the average of three readings was used for the analysis. Hypertension was defined by "JNC 7" as a systolic BP (SBP) ≥140 mm Hg or a diastolic BP (DBP) ≥90 mm Hg, or a self-report of taking antihypertensive medication or previously diagnosed by a physician.

2.6. Dietary sodium (Na) and potassium (K)

Dietary Na and K were assessed by food recall 2 × 24 hours and performed after the day of urine collection. Subjects were requested to maintain their normal eating habits during the survey period. The nutritionist asked the subjects to recall all foods and beverage consumed in the previous 2×24 h. One day of 24-h dietary recalls was selected randomly from Monday to Sunday in each individual, and another day when the day of urinary collection. To clear the portion size, nutritionists demonstrated food models and the photographic manual of household measures. The food recall was analyzed using Nutrition Data System (Nutrisurvey) and reported as mg/day.

2.7. Urinary 24 h

All participants were given written and verbal instructions how to collect 24-hour urine correctly. The first urine of the day was discarded, and all urine over the following 24 hours, including the first urine of the following day, was collected in the bottles provided. When the subjects returned the urine bottles to researchers the following day, they were asked to confirm the accuracy of their 24 h urine collection by asking whether any collection of urine was lost or forgotten and total volume of the collection was measured, Completeness of collection was determined by the subject's records and the output of creatinine in the 24-hours urine. Inaccurate urine collections defined as either a 24-hour urinary volume <500 mL or a urinary creatinine <5.0 mmol/day or extreme outliers for urinary creatinine >3 SD from the mean were excluded [26]. In those cases in which the collection of 24 h urine sample had to be repeated, further meetings were planned. So, each participant who meets study criteria but had inaccurate urine collections can be included again become subject by collecting urinary 24 h correctly.

2.8. Urinary and dietary Na/K ratio

Urinary sodium concentration and potassium concentration were analyzed and expressed as millimoles per liter. Urinary Na/K was calculated by dividing urinary Na by K. Similar to urinary Na/K ratio, dietary Na/K ratio was expressed as milligram per day was calculated by dividing dietary Na by K.

2.9. Statistical analysis

All data were checked for normality using the Kolmogorov Smirnov test. Sample characteristics were compared between HT status using *t* test or Mann Whitney test for continuous data (Table 1). Bivariate analysis to assess the correlation between Na, K, Na/K ratio and SBP/DBP was performed by Pearson or Spearman test (Table 2). Multivariable robust liniar regression models were used to evaluate the association of BP (dependent variable) with urinary and dietary Na/K ratio (independent variable) after adjustment for age, length of stay, BMI, and dietary Na/K ratio (for analysis urinary Na/K) or urinary Na/K ratio (for analysis dietary Na/K). To commit the potential effect of antihypertensive medication, sensitivity analyses with the exclusion of subjects consuming these medications were performed (Table 3). All statistical calculations were performed with Statistical Package for Social Science version 21 with a p-value<0.05 was significant.

3. Results

A total of 51 subjects completed the study. They averaged 56.98 ± 5.7 years of age, had a BMI of 25.96 ± 4.85 kg/m^2. Almost all subjects lived in the coastal area since birth, so the mean residence was almost similar to mean age (52.8 ± 12.57) years. From 51 subjects with BP measurements, 19 subjects (37.3%) were classified as hypertensive. Among those with HT, 15 subjects were taking antihypertensive drugs regularly. All subjects have participated actively in elderly community health program for five years.

The mean $\pm$ SD urinary Na of all subjects was 104.75 ± 59.25 mmol/d, urinary K was 20.52 ± 9.72 mmol/d, and urinary Na/K ratio was 5.28 ± 1.68. The dietary method showed that the mean Na intake was

Table 1
Baseline characteristics stratified by hypertensive status[1]

Variable	Total $n = 51$	Normotensive $n = 32$	Hypertensive $n = 19$	p
Age [years]	56.98 ± 5.7	57.19 ± 6.85	57.16 ± 3.45	0.98
Long time of residence [years]	52.8 ± 12.57	56.59 ± 7.16	56.53 ± 3.34	0.96
SBP [mm Hg]	132.25 ± 17.78	121.09 ± 9.89	151.05 ± 10.75	0.00*
DBP [mm Hg]	83.63 ± 10.3	77.03 ± 6.33	94.74 ± 4.24	0.00*
BMI [kg/m^2]	25.96 ± 4.85	24.26 ± 5.24	28.82 ± 1.36	0.001*
Physical activity index	21.45 ± 4.86	22.06 ± 4.81	20.42 ± 4.89	0.25
Urinary 24 h				
Volume [ml]	837.25 ± 330.13	818.75 ± 279.9	868.42 ± 407.6	0.61
Sodium [mmol/d]	104.75 ± 59.25	94.59 ± 41.13	120.53 ± 81.03	0.21
Potassium [mmol/d]	20.52 ± 9.72	21.19 ± 10.18	19.50 ± 9.08	0.57
Urinary Na/K ratio [mmol/mmol]	5.28 ± 1.68	4.74 ± 1.36	6.01 ± 1.89	0.015*
Clearance creatinine [ml/mnt]	94.06 ± 22.86	90.88 ± 2.11	99.42 ± 24.38	0.2
Dietary intake				
Fluid consumption [ml]	1400.91 ± 343.61	1377.71 ± 348.33	1439.98 ± 341.23	0.537
Energy [kkal/d]	1374.63 ± 303.13	1374.91 ± 261.82	1374.16 ± 370.38	0.993
Sodium [mg/d]	1247.8 ± 764.17	1091.23 ± 747.6	1511.49 ± 736.59	0.057
Potassium [mg/d]	1220.09 ± 955.8	1300.92 ± 680.61	1083.96 ± 391.11	0.211
Dietary Na/K ratio [mg/mg]	1.12 ± 0.74	0.89 ± 0.55	1.5 ± 0.87	0.011*

[1]Hypertensive subjects significantly different than normotensive subjects. *t-test. Significant, $p < 0.05$.

Table 2
Bivariate analysis: Correlation between sodium. Potassium and blood pressure

Variable	Systolic BP		Diastolic BP	
	r	p	r	p
Urinary 24 h				
Sodium	–0.053	0.713	–0.118	0.41
Potassium	–0.184	0.195	–0.153	0.283
Na/K ratio	0.377	0.006*	0.263	0.062
Dietary intake				
Sodium	0.196	0.169	0.16	0.27
Potassium	–0.19	0.182	–0.184	0.196
Na/K ratio	0.278	0.048*	0.232	0.101

*Pearson correlation. Significant. $p < 0.05$.

1247.8 ± 764.17 mg/d, dietary K was 1220.09 ± 955.8 mg/d, and dietary Na/K ratio 1.12 ± 0.74. Based on hypertensive status, the mean urinary and dietary Na/K ratio in hypertensive subjects were higher significantly than normotensive subjects with $p = 0.015$ and $p = 0.011$ respectively. Baseline characteristics stratified by hypertensive status are summarized in Table 1.

Table 3
Robust linier regression to show the association of BP [dependent variable] with urinary and dietray Na/K ratio [independent variable]

Independent variable†	N	Systolic BP Change [95% CI]	*P* value	Diastolic BP Change [95% CI]	*P* value
Urinary Na/K ratio					
Model 1		3.99[1.18–6.81]†	0.006*	1.48[–0.223–3.19]	0.087
Model 2		3.89[1.18–6.6]	0.006*	1.28 [–0.37–2.93]	0.125
Model 3		4.89[1.93–7.84]	0.002*	1.72[–0.189–3.63]	0.076
Dietary Na/K ratio					
Model 1		7.79[1.29–14.3]	0.020*	4.39[0.614–8.17]	0.024*
Model 2		4.25[–2.25–10.74]	0.195	2.26[–1.69–6.22]	0.256
Model 3		3.28[–0.38–2.14]	0.309	1.76[–2.43–5.94]	0.397

Model 1: Univariate model. Model 2: Multivariate model adjusted for age. Long time of residence. BMI. and dietary Na/K ratio [for analysis urinary Na/K] or urinary Na/K ratio [for analysis dietary Na/K]. Model 3: Model 2 with sensitivity analysis excluding subjects consuming antihypertensive medication (the number of subjects using antihypertensive medicine is 15 subjects). †Unit for change in BP is expressed as the percentage per each 1-unit change in the urinary and dietary Na/K ratio. *Significant, $p < 0.05$.

3.1. Bivariate correlation between sodium, potassium, and blood pressure

The analysis of bivariate correlation using Pearson or Spearman test demonstrated either Na or K alone in urinary and dietary did not correlate significantly with BP. However urinary and dietary Na/K ratio correlated significantly with SBP (Table 2).

3.2. The association of urinary and dietary Na/K ratio with Blood Pressure

Urinary Na/K ratio was independently associated with SBP. In the unadjusted model [model 1], SBP increased by 3.99 [95% CI:1.18, 6.81]; $p = 0.006$] for each 1-unit increase in urinary Na/K. This association remained significant event after adjustment for age, length of stay, BMI, dietary Na/K ratio (for analysis urinary Na/K) or urinary Na/K ratio (for analysis dietary Na/K), SBP increased by 3.89 [95% CI 1.18,6.6] for each 1-unit increase in urinary Na/K (model 2). Furthermore, urinary Na/K ratio was changed 4.89 with significance by excluding subject with antihypertensive medicine. In other hands, the association between urinary Na/K and DBP reported that no significant correlation both for the unadjusted model and adjusted model.

The association between dietary Na/K ratio and SBP/DBP showed that significant correlation only in the unadjusted model. However, it became not significantly in model 2 and model 3. Furthermore, associated with SBP in the univariate model, dietary Na/K increased almost twice than those in urinary Na/K. There were 7.79 (95% CI 1.29, 14.3) versus 3.99 (95% CI 1.18, 6.81).

4. Discussion

The present findings indicate that two methods both dietary and urinary Na/K ratio were correlated with SBP in older women in the urban coastal area. Moreover, findings in our study corroborate a systematic review of population studies that Na/K ratio was more strongly associated with HT and/or systolic and diastolic BP outcomes than either Na or K alone [12]. Our study also reported that either Na or K alone in both urinary and dietary did not correlate significantly with BP ($p > 0.05$). Some studies which applicable Na/K ratio more strongly associated with BP than Na and/or K alone were Mente et al. [6], Hu et al. [27], Yamori et al. [28], Ruixing et al. [29], Huggins et al. [26], Schroder et al. [30], and Xie et al. [31] studies.

Population studies that investigated the association between urinary Na and K and blood pressure in multiple countries are INTERSALT [10], PURE (Prospective Urban Rural Epidemiology) study [6], and INTERMAP (The International Study of Macro/Micronutrients and Blood Pressure) [26]. Among many countries involved in those studies, Indonesia is not included and there are limited studies about urinary 24 h Na and K intake in Indonesia. Recent study showed among all countries in Southeast Asia until 2013, only Singapore used the gold standard 24-hr urinary Na excretion to estimate intakes [13].

We used two instruments to measure Na and K intake; single urinary 24 h and food recall 2×24 h. Urinary excretions of Na and K are considered to adequately reflect the dietary intakes of these electrolytes, meanwhile, dietary Na and K often were reported underestimate or overestimate [13, 16]. However dietary recalls and urine analyses are often the most feasible methods for estimating Na and K intake [13, 14]. Our study demonstrated Na intake from dietary method was less than urinary, otherwise, K intake from dietary method was greater than urinary (Table 1). The Trial of Non-pharmacologic Intervention in the Elderly (TONE) study showed a similar result with our study; dietary recalls yielded estimates of Na and K intake that respectively averaged 22% less and 16% greater than those from urine assays [13]. However, our study differs from the previous study showing that Na intake measured by the dietary method is larger than 24-hour urinary method [14].

The mean of urinary Na/K ratio and dietary Na/K ratio in our study were 5.28 ± 1.68 and 1.12 ± 0.74 respectively and categorized as a high value since dietary guidelines demonstrated the normal range of dietary Na/K ratio was either 0.49 or 0.32 [32]. Most studies using dietary methods to assess Na/K ratio also showed high value of Na/K ratio were Hu et al. with the Na/K ratio of 3.34 [27]; Ruixing et al. of 1.8 [29]; Schroder et al. of 0.62 [30]; Bu et al. of 2 [33]; and Zhang of 1.41 [34]. Meanwhile, several studies applied 24-hours urine collection to assess Na/K ratio in adults [12]. There were Du et al. with the Na/K ratio of 4.9–2.8 [18]; Mirzaei et al. of 3.69 ± 1.58 [21]; Millen et al. of 1.41 [35]; Michel et al. of 3.71 [36]; Huggins et al. of 1.99 [26]; Redelinghuys et al. of 4.27 [37]; Yamori et al. of 4.55 [28]; Xie et al. of 6.1 [31]; Ortega et al. of 2.57 [38]; and Tran et al. of 2.44 [5].

The mean of sodium intake based on 24-h urinary excretion in our subjects was 104.75 ± 59.25 mmol/d. These averages were considerably lower than those reported in many populations in the world. Our result was surprising since the most adult populations have the mean Na intakes >100 mmol/day, and for many Asian countries, the mean intakes are >200 mmol/day [39]. Low sodium intake in our study may be explained by age, education, and energy intake of our subjects. Some countries from epidemiological studies demonstrated that low Na intake presented in women >50 years old, subjects with lower educated and low energy intakes [39, 40]. Furthermore, a coastal area in our study was located in the urban central city so the accessibility of health information and health care could be achieved easily. Following actively in health programme, our subjects might change their behavior by decreasing of salt intake on their food.

Mean dietary intakes of potassium in our subjects were 1220.09 ± 955.8 mg/day and only 20.52 ± 9.72 mg/d based on urinary 24j. It means very low or only 17–25% to compared Recommended Dietary Allowance (RDA). One causes of low potassium intake were the low intake of vegetables and fruits. Analysis fruit and vegetables from data Indonesian National Health Survey 2010 among adult female showed the mean of consuming fruit and vegetables was 139.7 ± 55.9 g/d which were lower than World Health Organization 400 g/d [41]. Moreover, recent study showed low consumption of fruit and vegetable contributed to low potassium intake [42].

The slightly low sodium and substantially low potassium intake in urban coastal dwellers might cause the Na/K ratio among our subjects become high enough to induce HT. It was revealed that both the mean urinary and dietary Na/K ratios in hypertensive subjects were higher significantly than normotensive subjects (Table 1). Moreover, urinary and dietary Na/K ratio correlated significantly with SBP (Table 2). There were similar to Hedayati et al. study at 3303 Dallas heart study age 30–60 years old showed that urinary Na/K ratio in hypertensive subjects was higher than normotensive [43]. Furthermore, INTERSALT study in 40 centers in the worldwide also revealed the relation of urinary Na/K ratio to SBP was highly significant ($p < 0.001$) [10].

The superiority of this study is we used 24 h urinary to measure Na and K intake because there are limited studies by measuring 24 h urinary Na and K in Indonesia [6, 10, 17, 26]. Furthermore, this study applied Na/K ratio for assessing dietary and estimating blood pressure at the population level and the previous studies revealed that Na/K ratio is a useful marker for nutrition surveillance in populations and can identify populations at high risk for nutrition-related chronic disease [10,44].

The weakness of our study is about the units of Na/K ratio. For additional note, the units of Na/K differ depending on the measurement method (mg vs mmol), so it may be difficult to compare and to examine the same methods with different units [44]. The assessing of Na and K intake by recent intake and single 24-h urine cannot be regarded to adequately reflect long-term dietary exposure. Multiple 24-hour urine samples collected over a period of several months would yield a better estimate of habitual intake [12, 37]. The results of our study can not be applied to the general population, but generalized only in the population with specific characteristics such as only older women with post menopause dwelling at urban coastal area.

In conclusion, this study supports the view that Na/K ratio is a useful marker for estimating BP since Na/K ratio is more strongly associated with blood pressure than either sodium or potassium alone. Both urinary and dietary Na/K ratios are potential surveillance tool that can assess and identify populations at high risk for HT in coastal area; assessing by urinary Na/K ratio is more recommended. The slightly low sodium and substantially low potassium intake in urban coastal dwellers might cause the Na/K ratio become high enough to induce HT. Studies in this scope may propose clues for a further understanding of its causes and be getting effective ways to decrease Na/K ratio in our population.

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Conflict of interest

The author(s) confirm that this article content has no conflict of interest.

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