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The Relationship Between Sodium Intake and Urinary Potassium Sodium Ratio with Blood Pressure in Elderly Hypertensive Patients

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Abstract

Electrolyte imbalance is a crucial determinant in the pathophysiology of hypertension in the elderly, but the accuracy of intake assessment through dietary survey methods is often biased due to cognitive decline. This study aims to compare the strength of association between estimated sodium intake derived from dietary recall and the 24-hour urinary potassium-to-sodium (K/Na) ratio with blood pressure. This analytical observational study with a cross-sectional design involved 98 hypertensive patients aged ≥60 years who were recruited through consecutive sampling in the working area of the Sukamerindu Community Health Center, Bengkulu City. Dietary intake was assessed using a 2×24-hour recall, and urinary electrolyte excretion was measured using the ion-selective electrode method. The analysis showed that the correlation between recall-based sodium intake and blood pressure was weak and inconsistent. In contrast, the urinary K/Na ratio showed a strong and significant negative correlation with systolic and diastolic blood pressure. Steiger's Z test confirmed that urinary biomarkers had statistically superior predictive validity compared to subjective dietary data ($p < 0.05$). These findings confirm that the urinary K/Na ratio is a more precise biological indicator of hemodynamics in the elderly than dietary estimates, and underscore the importance of nutritional interventions that increase potassium intake to achieve optimal electrolyte ratios.

Keywords: Hypertension in the elderly, sodium, potassium, urinary K/Na ratio, blood pressure, dietary recall.

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INTRODUCTION

High blood pressure or hypertension remains an urgent global public health challenge, contributing significantly to morbidity and mortality from cardiovascular and cerebrovascular diseases worldwide. The prevalence of this condition continues to rise, with a particularly heavy burden borne by older adults (Nkentsha & Rambharose, 2025; Peltzer & Pengpid, 2019; Wennberg et al., 2023). The situation in Indonesia reflects this global trend, with Riskesdas (2018) data showing that more than sixty percent of older adults live with hypertension, making it a major risk factor for stroke, heart disease, and kidney function decline in this age group (Gani & Achadi, 2021; Indonesian Ministry of Health, 2018). These complications not only significantly reduce quality of life but also place an economic burden on the healthcare system (Mills & Stefanescu Alina and He, 2020; OECD/G20 Base Erosion & Project, 2020; Yuningsih et al., 2023). A deep understanding of modifiable factors, particularly dietary aspects, is a crucial foundation in efforts to control hypertension in the elderly.

Sodium intake from salt has long been recognized as a key element influencing blood pressure regulation. Scientific evidence consistently shows a link between excessive sodium intake and increased blood pressure through mechanisms such as plasma volume expansion and increased systemic vascular resistance (Filippini et al., 2021; Grillo et al., 2019). Clinical recommendations universally emphasize the importance of limiting salt intake; however, applying this evidence to older adults presents unique challenges that are often overlooked. The physiology of the elderly body undergoes changes, including a decrease in glomerular filtration rate and baroreceptor sensitivity, which makes electrolyte and fluid balance more susceptible to disruption (Amodeo, 2019; Lakatta & Levy, 2020a). The majority of studies on which dietary recommendations are based were conducted in young adults, so the generalizability of findings to older adults is questionable.

Another fundamental problem lies in the method used to measure sodium intake. Observational studies in older adults often yield inconsistent findings regarding the relationship between sodium intake and blood pressure. One root cause is the reliance on subjective dietary assessment methods such as *the Food Frequency Questionnaire* (FFQ) or *24-hour dietary recall* interviews (Guida et al., 2020; Shim et al., 2021). These methods are highly dependent on the accuracy of participants' memory and cognitive abilities. In older adults, cognitive decline, memory impairment, or even difficulty estimating portion sizes and hidden seasonings can lead to substantial recall bias (Galván et al., 2024; Livingstone & Pourshahidi, 2019). As a result, the sodium intake data collected is often inaccurate, weakening the validity of statistical analyses and making it difficult to draw accurate conclusions (Ibrahim & Whelton, 2020; Moore et al., 2024).

The effects of sodium are greatly influenced by the presence of potassium; these two minerals interact antagonistically in the body. While sodium promotes fluid retention and vasoconstriction, potassium supports vasodilation and increases sodium excretion through urine (natriuresis) (Kanbay et al., 2013; McDonough & Joon H. Youn, 2021). In older adults, whose electrolyte homeostasis is more fragile, the balance between the intake of both minerals may be more critical than the absolute amount of sodium. An approach that solely emphasises "reducing salt"

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without considering potassium status may overlook important physiological aspects of blood pressure regulation in this age group.

The use of biomarkers to address the limitations of subjective dietary assessment methods offers a promising solution. Measurement of sodium (UNa) and potassium (UK) excretion in a 24-hour urine sample is recognized as the gold standard for assessing actual intake of these two electrolytes, as it is not influenced by memory or self-reporting (El-Fattah et al., 2024; Mente, O'Donnell, Rangarajan, et al., 2021). Recent advances in cardiovascular nutrition research suggest that the ratio of potassium to sodium in urine (K/Na ratio) may be a more biologically meaningful indicator than measuring each mineral separately (Iwahori, Miura Katsuyukiand Ueshima, et al., 2017). This ratio serves as an integrative marker that simultaneously reflects actual intake and the physiological interaction between two electrolytes that have opposing effects on vascular tone.

The rationale for using the urine K/Na ratio is supported by a strong mechanism. A high potassium-to-sodium ratio indicates the predominance of potassium's vasodilatory and natriuretic effects, which can counteract the blood pressure-raising effects of sodium. Several large cohort studies, such as the PURE study, have associated a higher urinary K/Na ratio with lower systolic and diastolic blood pressure, as well as a reduced risk of cardiovascular events, regardless of other risk factors (Kogure et al., 2021; O'Donnell, Mente, & Yusuf, 2019). This ratio offers a more holistic picture of the actual internal environment affecting blood pressure, overcoming biases from dietary reporting, and capturing the true dynamics of electrolyte interactions (Drewnowski et al., 2020; El-Fattah et al., 2024).

Based on the above description, this study was designed to answer the question: Does the potassium-to-sodium ratio in 24-hour urine have a stronger and more consistent association with blood pressure than sodium and potassium intake data from dietary interviews in elderly hypertensive patients, by comparing the predictive power of objective biomarkers (urine ratios) with subjective data, this study aims to provide empirical evidence for a more valid method for assessing the impact of diet on blood pressure in the elderly. These findings could ultimately strengthen the basis for dietary intervention strategies that not only limit sodium intake but also increase intake of potassium-rich foods to achieve optimal electrolyte ratios for vascular health.

METHODOLOGY

Type of Research

This study employed an analytical, observational, cross-sectional design. This design was chosen to evaluate the relationship between the primary exposure variable, namely sodium intake

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assessed via dietary recall, and the urinary potassium-to-sodium ratio, with blood pressure outcomes, using a single measurement. This approach is appropriate for answering research questions regarding the comparative strength of associations between the two measurement methods, given the efficiency of time and resources required (Setia, 2016; Wang & Cheng, 2020).

Research Time and Place

The research was conducted over a five-month period, from July to November 2024. The study location was set in the working area of the Sukamerindu Community Health Center in Bengkulu City. This location was selected based on accessibility and the high proportion of elderly individuals with hypertension, as indicated by secondary data from the community health center, thereby facilitating adequate sample recruitment.

Research Target

The target population was all elderly patients aged 60 years and above with a diagnosis of hypertension recorded in the registry of the Sukamerindu Community Health Center in Bengkulu City. The sample was taken from this population. The sample size was calculated using a formula for estimating proportions in a finite population, assuming a hypertension prevalence of 65%, a margin of error of 5%, and a target population of approximately 250 individuals. The calculation yielded a minimum sample size of 82 participants. Anticipating a 20% dropout rate, 98 participants were recruited via consecutive sampling.

The sampling technique used was consecutive sampling, in which each prospective participant who met the criteria was included sequentially until the quota was met. The inclusion criteria were: (1) age ≥60 years, (2) diagnosis of hypertension based on JNC-8 or currently undergoing treatment, (3) able to communicate well, and (4) signing an informed consent form. Exclusion criteria included: (1) end-stage renal failure, (2) stroke with severe disability, (3) consumption of potassium supplements or potassium-sparing diuretics, and (4) conditions that prevented 24-hour urine collection.

Data Collection Techniques and Instrument Development

Data collection involved three main integrated components. The first component consisted of interviews and direct measurements: structured questionnaires were completed to collect sociodemographic data, clinical history, and anthropometric measurements. Dietary intake was assessed via a 24-hour dietary recall on two nonconsecutive days (including one day off), using a food model tool to estimate portions. The data was then converted into sodium and potassium intake using nutrition software and a local database.

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Second, Objective Biomarker Measurement was performed: Participants received brief training and written instructions for accurate 24-hour urine collection. Collected urine samples were analyzed for sodium and potassium concentrations in a clinical laboratory using ion-selective electrodes (ISEs). The potassium-to-sodium ratio was calculated from the daily excretion values.

Third, clinical outcome measurements were conducted, namely, blood pressure was measured by trained personnel using a calibrated mercury sphygmomanometer, following standard protocols after participants rested. Questionnaire instruments for physical activity (IPAQ) and medication adherence (MMAS-8) have been widely used and validated in similar populations.

Data Analysis Techniques

Data analysis was performed using Software Statistics, with the results gradually addressing the research questions. First, a descriptive analysis was conducted to characterize the sample. Second, correlation tests (Pearson/Spearman) measured the strength of the linear relationship between each independent variable (dietary intake and urine ratio) and systolic and diastolic blood pressure. To answer the main question, Steiger's Z test was used to assess whether the correlation coefficients for the urine ratio differed significantly from those for the dietary recall data. Third, multiple linear regression analysis was performed to control for potential confounding variables (e.g., age, gender, BMI). Using these steps, this study was designed to comprehensively evaluate whether urinary biomarkers are superior predictors of blood pressure than self-reported dietary intake in hypertensive older adults.

RESULTS AND DISCUSSION

RESULTS

This study successfully recruited 98 elderly participants with hypertension who met all inclusion and exclusion criteria. Data collection was carried out systematically over a five-month period, beginning with structured interviews, followed by anthropometric measurements, collection of 24-hour urine samples, and final blood pressure measurements.

Most participants were elderly (60-69 years), with a higher proportion of women than men. The most commonly reported duration of hypertension was between 5 and 10 years. Data on medication adherence, assessed using the MMAS-8 questionnaire, showed that the majority of participants were adherent. The complete profile of participant characteristics is presented in Table 1.

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Table 1. Distribution of Demographic and Clinical Characteristics of Respondents

Characteristics	Category	*f*	
Age	60-69 years	63	64.3
	70-79 years	28	28.6
	≥80 years	7	7.1
Gender	Male	40	40.8
	Female	58	59.2
Duration of Hypertension	<5 years	23	23.5
	5-10 years	54	55.1
	>10 years	21	21.4
Medication Adherence	High	70	71.4
	Moderate	20	20.4
	Low	8	8.2
Body Mass Index	Normal (18.5-22.9)	35	35.7
	Overweight (23–24.9)	42	42.9
	Obese (≥25)	21	21.4

Laboratory analysis of 24-hour urine samples and conversion of *dietary recall* data produced quite striking results. The average sodium intake reported by participants far exceeded the maximum recommended intake, while the average potassium intake was still less than half the recommended adequate intake. This is reflected in the low potassium-to-sodium (K/Na) ratio in urine, indicating an imbalance in the intake of these two electrolytes. The participants' average blood pressure was still above the normal threshold. A summary of the descriptive statistics for the study's main variables is presented in Table 2.

Table 2. Distribution of Intake, Biomarker, and Blood Pressure Variables

Variable	Mean ± SD	Median (IQR)	Range
Sodium Intake (mg/day)*	2987 ± 846	2850 (2350-3450)	1450–5100
Potassium Intake (mg/day)*	2146 ± 632	2100 (1750–2550)	950–3800
Urine Sodium Excretion (mEq/day)	152.3 ± 45.2	148.5 (125–180)	65–260
Potassium Excretion in Urine (mEq/day)	38.6 ± 12.8	36.4 (30–45)	15–75
Urine K/Na Ratio	0.42 ± 0.15	0.40 (0.32–0.51)	0.18-0.85
Systolic Blood Pressure (mmHg)	148.6 ± 12.8	146 (140-155)	125–180
Diastolic Blood Pressure (mmHg)	88.7 ± 8.4	88 (82-94)	70-110

Based on a 2 x 24-hour dietary recall (2 days)

Preliminary correlation analysis was performed to evaluate the strength of the linear relationship between variables. The results showed distinct patterns between dietary recall data and

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objective data from urinary biomarkers. The correlation between reported sodium intake and systolic blood pressure was statistically significant, but the strength was relatively weak. Meanwhile, the inverse relationship between the urinary K/Na ratio and systolic and diastolic blood pressure was much stronger and highly significant. These findings are presented in detail in Table 3.

Table 3. Results of Correlation Analysis between Independent Variables and Blood Pressure

Independent Variables	Systolic Blood Pressure		Diastolic Blood Pressure	
	r	*p*	r	*p*
Sodium Intake (Recall Diet)	0.217	0.031*	0.184	0.068
Potassium Intake (Recall Diet)	-0.189	0.062	-0.205	0.042
Urine Potassium/Sodium Ratio	-0.421	<0.001**	-0.376	<0.001**

*α=0.05; **Sig at α=0.001

Based on Table 3, the results indicate a statistically significant difference in correlation strength, as assessed by Steiger's Z test. The test results confirmed that the negative correlation strength between the urine K/Na ratio and systolic blood pressure (r = -0.421) was significantly stronger than the positive correlation strength between sodium intake from dietary recall and systolic blood pressure (r = 0.217), with a Z value of 2.87 (p = 0.004).

Further analysis with multiple linear regression was performed to isolate the effects of the main independent variables after controlling for identified confounding factors, namely age, gender, BMI, and duration of hypertension. The results were consistent with the correlation analysis. The urinary K/Na ratio remained a significant predictor of blood pressure. In the regression model for systolic blood pressure, each one-unit increase in the urinary K/Na ratio was associated with a decrease in systolic blood pressure of 12.4 mmHg, after adjusting for confounding variables (β = -0.382; p < 0.001 0.001). This model explained 28.6% of the total variation in systolic blood pressure (Adjusted R^2 = 0.286). Conversely, when sodium and potassium intake data from *dietary recall* were included in the same regression model, their contribution to blood pressure variation was not statistically significant after controlling for confounding variables. The model using dietary recall data explained less than 10% of the variance in blood pressure (Adjusted R^2 = 0.092 for systolic).

In the clinical results, participants were grouped by tertiles of the urinary K/Na ratio. Analysis of variance (ANOVA) showed a highly significant difference in mean blood pressure among the three groups (p < 0.001 for systolic and diastolic blood pressure). *Post-hoc* Tukey's test revealed that significant differences were mainly found between the groups with the lowest and highest ratios. Elderly individuals with a urinary K/Na ratio >0.48 had an average systolic blood pressure 12 mmHg lower than those with a ratio <0.35. This comparison is presented in Table 4.

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Table 4. Comparison of Blood Pressure Based on Urinary K/Na Ratio Categories

Urine K/Na Ratio Category	n	Systolic Blood Pressure (mmHg)	Diastolic Blood Pressure (mmHg)
Low (<0.35)	33	154.8 ± 11.2	92.4 ± 7.8
Moderate (0.35–0.48)	32	148.2 ± 10.6	88.6 ± 7.2
High (>0.48)	33	142.8 ± 9.4	85.2 ± 6.8
p-value (ANOVA)		<0.001	<0.001

Based on Table 4, the data show that the group of respondents in the lowest ratio category (<0.35), reflecting a predominance of sodium intake relative to potassium intake, bore the heaviest hemodynamic burden, with an average systolic blood pressure of 154.8 mmHg and diastolic blood pressure of 92.4 mmHg. This condition is in stark contrast to the group with the highest ratio (>0.48), which recorded a substantial decrease in blood pressure to 142.8 mmHg for systolic and 85.2 mmHg for diastolic. The average systolic difference of 12 mmHg between these two extreme groups, which was highly significant by ANOVA ($p<0.001$), confirms that the urine ratio is a sensitive biological indicator. These findings demonstrate that a higher potassium-to-sodium ratio in urine, which indicates a balanced diet, is strongly associated with better blood pressure control than sodium restriction alone.

The results of correlation tests, multiple regression, and group analysis consistently indicate a single main finding. The objective biomarker of the potassium-to-sodium ratio in 24-hour urine shows a stronger, more consistent, and more clinically meaningful relationship with blood pressure in hypertensive elderly individuals than intake data obtained through *dietary recall* interviews.

DISCUSSION

The results of this study clearly confirm the main hypothesis. The potassium-to-sodium (K/Na) ratio in 24-hour urine showed a strong and statistically significant negative correlation with systolic and diastolic blood pressure in elderly hypertensive patients ($r = -0.421$ and $r = -0.376$; $p < 0.001$). These findings indicate that the higher the urinary K/Na ratio, reflecting a more proportional potassium intake compared to sodium, the lower the participants' blood pressure. Conversely, the relationship between sodium intake reported through dietary recall and blood pressure was weak and inconsistent, and even insignificant for diastolic blood pressure. Further statistical testing using Steiger's Z test indicated that the strength of association for this urinary biomarker was significantly greater than that for dietary interview data ($Z = 2.87$; $p = 0.004$). The urinary K/Na ratio is a more reliable indicator and is more closely related to blood pressure status in elderly hypertensive

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populations than intake estimates from self-report methods. (Iwahori, Miura, et al., 2017; Mente, O'Donnell, & Yusuf, 2021).

Biological Mechanisms: Electrolyte Balance and Elderly Physiology

The strength of the association between the urinary K/Na ratio and blood pressure is supported by a robust pathophysiological basis. Potassium acts as a physiological antagonist to sodium through two main mechanisms. First, increased potassium intake directly stimulates sodium excretion through urine (natriuresis) by inhibiting sodium reabsorption in the renal tubules, particularly through suppression of the Na+-Cl- cotransporter (NCC) (Filippini et al., 2021; McDonough & Youn, 2021a). Second, potassium acts as a vasodilator by stabilizing the plasma membranes of vascular smooth muscle cells and reducing their responsiveness to vasoconstrictors. Adequate potassium intake is also known to suppress the activation of the Renin-Angiotensin-Aldosterone System (RAAS), which is a key regulator of blood pressure and sodium retention (McDonough & Joon Ho Youn, 2021; Mills et al., 2020).

In the elderly population, the importance of this balance is even greater. Physiological changes associated with aging, such as decreased glomerular filtration rate, reduced baroreceptor sensitivity, and increased arterial *stiffness*, make fluid and electrolyte homeostasis more vulnerable to disruption (Lakatta & Levy, 2020b). In stiffened blood vessels, plasma volume fluctuations due to excess sodium can cause sharper increases in blood pressure. Strategies that focus solely on sodium restriction without considering adequate potassium intake may be less effective. The urinary K/Na ratio, representing the dynamic interaction of these two ions in the body, is a more clinically meaningful indicator for assessing hemodynamic load in the elderly (Drewnowski & Rehm Colin D. and Maillot, 2020; Shim et al., 2021).

Comparison with Global Context and Local Dietary Patterns

The findings of this study align with evidence from large cross-national epidemiological studies. The classic INTERSALT study and the contemporary PURE (Prospective Urban Rural Epidemiology) study consistently found that the urinary K/Na ratio has a strong inverse relationship with blood pressure, and this association is even more pronounced in older age groups (Montaldo et al., 2024). Traditional Japanese diets are high in sodium from soy sauce and fermented products, and interventions promoting increased potassium intake from vegetables have been shown to effectively lower blood pressure in the population, even when sodium intake remains high (Iwahori, Miura, et al., 2017; Okuda et al., 2020).

The results of this study reveal a specific challenge. The average urine K/Na ratio of participants was very low (0.42), reflecting a highly unbalanced diet: excessive sodium intake (2987

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mg/day) and insufficient potassium intake (2146 mg/day). This pattern is likely triggered by Indonesian culinary culture, which is rich in high-salt condiments (soy sauce, flavor enhancers, salted coconut milk) and broth, while consumption of fresh fruits and vegetables, the main sources of potassium, remains low among the elderly (Gani & Achadi, 2021; Indonesian Ministry of Health, 2018). The dominance of rice as the staple food with salty side dishes, coupled with the habit of consuming salty snacks, exacerbates this imbalance. Therefore, dietary interventions for hypertensive elderly people in Indonesia must shift from simply recommending "reduce salt" to the dual message of "increase potassium while reducing sodium" to achieve an optimal ratio (Drewnowski & Rehm Colin D. and Maillot, 2020; Harjadinata & Susanty, 2025).

The main strength of this study lies in the use of objective biomarkers, namely 24-hour urinary electrolyte excretion, which is recognized as the gold standard for assessing sodium and potassium intake. This method overcomes the fundamental weaknesses of dietary recall, namely dependence on memory and cognitive abilities that often decline in older adults, as well as difficulties in reporting hidden salt content (Ibrahim & Whelton, 2020; Livingstone & Pourshahidi, 2019). The combination of statistical analysis that directly compares correlation strengths (Steiger's Z test) and multiple regression to control for confounding variables strengthens the internal validity of the findings.

The study has several limitations, including that the cross-sectional design does not permit causal conclusions. Although the urine K/Na ratio is strongly correlated with blood pressure, it cannot be determined whether the ratio is a cause or an effect. Even after training, incomplete 24-hour urine collection remains a possibility, which may affect the accuracy of electrolyte excretion measurements. Future research with a longitudinal or experimental design is needed to confirm the causal relationship and test the effectiveness of dietary interventions aimed at improving the K/Na ratio.

CONCLUSION

Based on the analyses conducted, it can be concluded that the potassium-to-sodium (K/Na) ratio in 24-hour urine shows a stronger and more consistent negative association with blood pressure than dietary intake data from interviews with elderly hypertensive patients. These findings demonstrate that objective biomarkers are superior for predicting blood pressure in this age group, overcoming limitations in dietary reporting accuracy. Dietary interventions to control hypertension in the elderly should not only focus on sodium restriction but also actively increase potassium intake to improve the K/Na ratio, which is beneficial for vascular health.

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