

Estimating 24 Hour Sodium Urine from Spot Urine: A Correlation Model Among Aged 25-64 in Indonesia

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Received: February 26, 2021 Accepted: April 15, 2021 Online Published: May 8, 2021

doi:10.5539/gjhs.v13n6p49

URL: <https://doi.org/10.5539/gjhs.v13n6p49>

Abstract

Introduction: Excess salt intake is known to raise blood pressure and in turn increase the risk of cardiovascular disease. Data and information on sodium consumption in Indonesia is limited, while examination method using 24-hour urine examination is a complex method to apply in population based survey. **Objective:** to estimate value of spot urinary excretion against 24-hour urine values and correction factors.

Method: Validation was carried out through 24-hour urine and spot urine examination, in 423 individual aged 25-65 years in the Kebun Kelapa Village, Bogor City, Indonesia in 2017. Urine sodium examination method was carried out by laboratory examination inductively coupled plasma optical emission spectrometry (ICP-OES). Accuracy and precision are valued by paired test correlations and mean differences. The coefficient of determination (R Square) is calculated for sodium intake estimation and its correction factors.

Results: The sodium value of morning spot urine has better precision and stronger correlation with the sodium value of 24-hour urine than the sodium value of afternoon spot urine. The difference in average morning sodium urine with 24-hour urine sodium according to age and sex was not significantly different (t test 0.30 and p = 0.77), had a positive and moderate correlation (paired r = 0.50 and p = 0.00). The average difference between the estimated evening urine sodium spot was different (t test = 7.32 and p = 0.00), and the correlation was very weak (r = 0.25; p = 0.00).

Conclusion: the urine content / sodium spot level was accurate to estimate urine sodium value / content 24 hours.

Keywords: 24 hour sodium urine, spot urine

1. Introduction

Excess salt intake is known to cause raised blood pressure and hypertension that in turn directly or indirectly cause heart problems and diseases (including coronary heart disease, CHD / CHD; and vascular heart, CVD) (Campbell et al., 2012; Cappuccio, Capewell, Lincoln, & McPherson, 2011; Hawkes & Webster, 2012; Feng, He, Li, & MacGregor, 2013). Heart disease and stroke are the main causes of death in Indonesia. The prevalence of hypertension of Indonesian people aged older than 18 years is quite high, namely 25.8% (National Institute for Health Research & Development [NIHRD], 2013). The Indonesian Food Consumption Survey data in 2014 shows that the average of sodium intake of the Indonesian population was 2764 mg/day, 52.7 percent of the population consume more than 2000 mg/day (Prihatini, Permaesih, & Julianti, 2017). WHO suggests the recommended amount of consumption of no more than 5 grams of salt per day which correspond to 2000 mg of sodium. A nationwide efforts to limit populations salt consumption can prevent the occurrence of diseases and deaths associated with excessive sodium consumption. This has been proven in various countries including China, England (UK), Europe, Japan, North America (Okuda et al., 2014). This effort is expected to be followed by other countries including Indonesia. Indonesia's national sodium data is needed, both as a program's baseline data to limit consumption of sugar, salt, fat and to monitor the effectiveness of the intervention program implemented.

The Indonesian Ministry of Health seeks to protect the community from NCD (NonCommunicable Diseases)

through the recommendation of reducing the consumption of salt and control people's habits (behavior, health knowledge due to excessive salt consumption). The Ministry of Health's efforts to protect the public from the risk of getting the disease have not reached expectations because information on consumption behavior related to sodium and the magnitude of the problem of sodium intake in Indonesia are still very limited. The most accurate value of sodium intake is through 24-hour urine sodium excretion, but this examination is expensive and difficult to apply to surveys in the community. Examination of spot urine can be used to estimate the value of urinary sodium excretion 24 hours, but requires validation and correction factors (Ji et al., 2012).

This study validates the examination of current / spot sodium urine excretion (morning and evening) as an estimated 24-hour urine sodium value. In this paper, the accuracy and precision of spotted urine examination (morning or evening) will be conveyed for estimating 24-hour urine sodium levels, and conversion rates and correction factors (Estimation Formulas) sodium urine levels results of spot urine excretion in estimating 24-hour urine value.

2. Method

2.1 Study Design

This research is a validation study of examination methods and behavioral surveys conducted cross-sectionally. Validation was carried out between the results of sodium excretion in morning spot urines and afternoon spots with laboratory examination (ICP), compared with 24-hour urine sodium secretion values as gold standard. Estimated 24-hour sodium excretion rate is calculated based on the PAHO formula, namely: the value of spot urine examination results divided by the value / creatinine spot examination results multiplied by 24-hour urine examination value. The research was conducted in Bogor City, West Java. Data collection was carried out from September to December 2017.

2.2 Population and Sample

The population of this study were residents aged 25 years and over who lived in Bogor City, West Java. The sample was determined to follow the validation protocol for 24-hour urine and urine examination methods.

The number of samples was calculated based on the number of changes in the minimum urine excretion and the standard deviation value obtained by the minimum number of samples per age group and gender were 120 people with rounding for non-response estimation, it took 150 people in each age group and 2 sex groups (2x2 groups) so the total sample needed were 150 people x 4 groups = 600 people. Age groups include: 1). 25 - 49; 2) 50+ years. This sample size calculation referred to the 24-hour urine intake survey guidelines from WHO PAHO page 12 (WHO/PAHO, 2010).

The sample (participants) were selected purposively according to the inclusion and exclusion criteria and the necessary number of participants in each sub-group (age, sex). Inclusion criteria in accordance with the overall research protocol included: participants were settlers who live for more than one week or not commuters, aged 25 years and above, not being disturbed or suffering from diseases related to urinary / sodium excretion (during data collection), not taking medication, supplements and or herbs related to urinary / sodium excretion (the list will be included) in the past month, can be invited to collaborate (cooperative). Participants who were pregnant or breastfeeding, have special needs (physical and physical disabilities) and have severe illness were excluded.

Data collection was carried out by a data collection team consisting of 6 Nutrition Scholars. Before conducting data collection, enumerators and supervisors received special training. The teacher was a core research team from the Health Research and Development Agency that has appropriate competencies.

The method of urine collection was done for 24 hours, which ~~is to~~ started from waking up until the next day. Urine came out shortly after waking up was not accommodated. Urine that came out next, for example at 5 am was accommodated until 5 am the next day. Every urine that came out must be accommodated in the container provided and recorded in the form provided. Collection of morning urine was when you urinated around 8 am to 9 am. Collection of spotted urine during the afternoon was when urinated around 2 pm until 3 pm During the collection of urine, the urine collection container must always be closed and placed in a cool place (the room was far from the heat source) and protected from direct sunlight. Urine that came out along with defecating must still be accommodated (do urinate first).

Calculation of estimated 24-hour urine excretion sodium levels was calculated based on the PAHO formula (WHO/PAHO, 2010) :

$$\text{Estimated 24-hour urine sodium excretion (mEq)} = \frac{\text{sodium spot urine } \left(\frac{\text{mEq}}{\text{L}}\right)}{\text{creatinine spot } \left(\frac{\text{mg}}{\text{L}}\right)} \times 24 \text{ hour creatinine (mg)} \quad (1)$$

Estimated sodium value of 24-hour urine excretion was calculated in 4 groups / sub-samples including gender (male, female) and three age groups (25-40; 41-55; 55+ years). 24-hour urine sodium examination results with ICP was used as the gold standard.

The precision of the spot urine examination value in estimating the sodium value of 24 hours urine was calculated based on the magnitude of the difference in mean value and α value (p value) from the paired test difference in mean value and standard deviation. The greater the p-value, shows the difference in the value of the examination results were not significantly different (the same) that indicates the magnitude of the difference between 24-hour urine and spot urine. Precision calculations were performed according to age group and gender.

Results accuracy of the examination, was assessed based on the correlation coefficient based on the r value of the paired test. The coefficient of determination (R Square) from the results of linear regression analysis with the fit model, was calculated to determine the ability of individual predictions / estimates. Correlation coefficient and Square R from conventional spot urine examination results and examination results with a digital device in estimating the results of 24-hour urine examination were used as a basis for assessing the accuracy of examination results on each type of examination instrument. Correlation calculations were carried out in each sub-sample age group and gender. The strength of the correlation was considered strong if $r > 0.7$, moderate if $0.5 < r < 0.7$, weak correlation if $0.3 < r < 0.5$ and very weak or no correlation if $r < 0.3$. Examination of sodium spot urine was considered to be more accurate if the coefficient of determination (R squared) obtained from the estimation calculation was directing toward positif, as high R-squared may not always indicates good model.

3. Results

Data collection was carried out for 12 days, including briefing of ways to collect urine. Laboratory tests, especially creatinine, were carried out directly on the day of urine delivery. Urine examination (ICP, digital test with Spotchem, and digital test Easylyte) which cannot be directly implemented on the day of urine delivery due to limited examination facilities, was immediately stored in the refrigerator with a temperature of minus 80 degrees C. The number of participants who can collect their data in full (24-hour urine, morning spot urine, afternoon spot urine) were 625 people. Table 1 shows that there were more female than male participants. Respondents age were ranging from 25 years to 65 years with average of 48.34 years, and more than 50% of respondents were 41-55 years.

Table 1. Respondents Characteristics

Characteristics	n	%	Mean
Sex			
Males	297	47.5	-
Females	328	52.5	-
Age (years)			
25 – 40	149	23.9	36.03
41 – 65	476	76.1	52.19
Total	625	100.0	48.34

Coronary Heart Disease (CHD), diabetes mellitus (DM), and Stroke are Non-Communicable Diseases (NCD) that can affect the kidneys in producing urine, related to the drugs consumed and metabolic disorders that occur in the disease. To get more specific analysis results, participants who have the disease were excluded from the next analysis, and need to be analyzed specifically.

The presence or absence of CHD experienced by participants was determined by a coronary heart specialist based on the results of ECG examination and clinical interview. The presence or absence of a Stroke disorder was based on the results of a neurological examination by a neurologist. While the presence or absence of DM disease was determined based on the results of clinical interviews and examination of blood glucose (fasting and 2 hours of glucose loading). The number of participants who did not have NCD and further analysis was 423 people.

3.1 Estimation Value, Mean Different and Correlation

The estimated sodium value of 24 hours is calculated by the PAHO formula, namely; Y (urine sodium estimation 24 hours) = {sodium spot (X) / (creatinine spot urine value) mg or g/ μ g creatinine x (expected 24-h creatinine

excretion value 24 hours)}. Participant exclusion was conducted according to the results of the NCD risk factor cohort study, which was issued in November 2017. The results of data analysis in participants who did not suffered certain non communicable diseases (n = 423).

Table 2. Mean Difference and Correlation of 24hrs Sodium Urine in Estimation Based on Morning Sodium Spot Urine (mg/day)

Characteristics	n	24 hrs sodium urine (ICP lab)		Morning sodium spot urine ICP		Mean difference			Correlation	
		mean	SD	mean	SD	difference	t Test	p	r	p
Sex										
Males	223	3011.5	1373.7	3078.5	2265.9	67.0	0.51	0.61	0.51	0.00
Females	200	3051.8	1295.5	2916.7	2288.2	-135.1	0.97	0.34	0.49	0.00
Age (years)										
25 – 40	135	3251.2	1320.6	3336.2	2472.4	84.9	0.47	0.64	0.52	0.00
41 – 65	288	2927.1	1332.7	2845.3	2163.4	81.7	0.73	0.47	0.49	0.00
Total	423	3030.5	1335.9	3002.0	2275.2	28.5	0.30	0.77	0.50	0.00

Note. Total subject: 423 people and exclude subject with stroke, coronary heart diseases and diabetes.

Table 2 shows that there is no significant difference between the mean sodium urine from the estimation results based on the morning spot urine and ICP examination with 24-hour urine average (t test = 0.30 and p = 0.77). The average difference in estimated sodium urine with 24 hours of urine sodium (examination) according to sex was found to be insignificant, with p = 0.61 in men and p = 0.34 in women.

The difference in mean sodium urine estimation with morning spot, based on ICP examination according to age group was also found to be insignificant (p> 0.5).

Paired test of individual correlation between sodium urine estimation at morning spot based on ICP examination with 24 hours (examination) urine sodium was found to be significantly positive with moderate correlation (r = 0.50 p = 0.00). Correlation according to sex was also found to be moderate, both in men (r = 0.51; p = 0.00) and women (r = 0.49; p = 0.00). Likewise the correlation according to age group. In the age group of 25-40 years, a moderate correlation was found (r = 0.52; p = 0.00), in the 41-65 year age group it was weak correlation (r = 0.49; p = 0.00).

Table 3. Mean Difference and Correlation of 24hrs Sodium Urine in Estimation Based on Evening Sodium Spot Urine (mg/day)

Characteristics	n	24 hrs sodium urine (ICP lab)		Evening sodium spot urine ICP		Mean difference			Correlation	
		mean	SD	mean	SD	difference	t Test	p	r	p
Sex										
Males	223	3011.5	1373.7	6372.8	8360.0	3361.3	6.15	0.00	0.24	0.00
Females	200	3051.8	1295.6	4947.7	6850.7	1895.9	4.05	0.00	0.27	0.00
Age (years)										
25 – 40	135	3251.2	1320.6	5637.0	5749.9	2385.8	5.06	0.00	0.31	0.00
41 – 65	288	2927.1	1332.1	5728.1	8487.6	2801.1	5.74	0.00	0.23	0.00
Total	423	3030.5	1335.9	5699.0	7713.2	2668.5	7.32	0.00	0.25	0.00

The average difference between the estimated afternoon sodium spot urine based on ICP examination with 24-hour urine (examination) was found to be different in terms (t test = 7.32 and p = 0.00). The positive correlation was found to be significant with r = 0.25 (p = 0.00). The average 24-hour sodium estimation with an afternoon sodium

spot urine based on ICP examination was found to be higher (5699.0 mg) than 24-hour urine sodium examination results (3030.5 mg). The difference in standard deviation was found to be very large (SD = 7713.2 mg vs. 1353.9 mg).

The mean difference according to gender and age group was also found to be always significant ($p = 0$). Both by sex and by age group, the average urine estimate of 24 hours based on sodium spot urine in the afternoon with ICP examination tends to be greater than the mean sodium urine 24 hours (examination), with a higher standard deviation.

The difference in mean urine estimation 24 hours based on sodium spot urine afternoon from the results of ICP examination with 24 hour urine (examination) according to age groups was also found to be significant. According to age group, the average estimated urine sodium 24 hours based on the afternoon spot urine with ICP examination tends to be higher than the mean urine 24 hours (examination), as well as the standard deviation.

Paired test correlation between urine sodium estimated value based on spot urine afternoon ICP results with urine 24 hours (examination) was found to be significant, but with very weak strength ($r = 0.25$ $p = 0.00$). Correlation according to gender was found to be very weak ($r = 0.24$ in men and $r = 0.27$ in women). Whereas according to the age group also found positive association ($r = 0,24 - 0,38$).

3.2 Regression Analysis of Linear Model Fit

Table 4 shows the results of multivariate linear regression analysis with a fit model, in order to determine the estimation of 24-hour urine sodium from the results of spot urine examination. Multivariate linear regression analysis was performed on data sets with exclusion of CHD, DM and stroke ($N = 423$), with morning spot urine sodium test results.

Table 4. Linear Regression Model of Fit of 24 hour Sodium Urine Based on Morning Spot Urine ($N=423$)

Variable	Standardized Coefficients β	t	p	R Square adjusted
ICP laboratory test				
Sodium Urine (Na/K x K24 hours)	0.47	11.18	0.00	0.290
Age (years)	-0.10	-2.49	0.01	
Body Mass Index (BMI)	0.16	3.95	0.00	
Without correction of creatinine value				
Sodium Urine (mg/24hrs)	0.45	10.60	0.00	0.274
Age (years)	-0.09	-2.30	0.02	
Body Mass Index (BMI)	0.14	3.40	0.00	

The variables included in the analysis were age, sex, and BMI. Based on the fit model multivariate linear regression analysis, the factors found to affect the estimated urine value of 24 hours of individual morning spot urine sodium values ($p < 0.05$) were age and body mass index.

Through correction of sodium spot urine value with creatinine value (Sodium Spot urine (Na / KSpot x K24h), estimation of urine sodium 24 hours based on morning sodium spot urine from ICP examination has R Square 0.290. The analysis results obtained β Standardized Coefficients for Sodium (Na / KSpot urine x K24 hours) = 0.47, for Age = - 0.10, and for BMI = 0.16. Overview of linear regression lines and distribution of estimated values can be seen in Figure 1. The regression equation was $Y = 0,47$ (Natrium/Kreatinin morning Urine Spot x 24 hours creatinine) - 0,10 (age) + 0,16 (BMI).

Without correction of creatinine value, a 24-hour urine sodium estimation based on sodium of morning spot urine from ICP examination has R Square 0.274. The analysis results obtained Standardized Coefficients β for Sodium = 0.45, for Age = - 0.09, and for BMI = 0.14. The regression equations were the following $Y = 0,45$ (Natrium morning spot urine) - 0,09 (age) + 0,14 (BMI). The description of linear regression lines and the distribution of estimated values can be seen in Figure 2. It can be seen from Figure 1 and Figure 2 that it may need to run residual analysis for model correction.

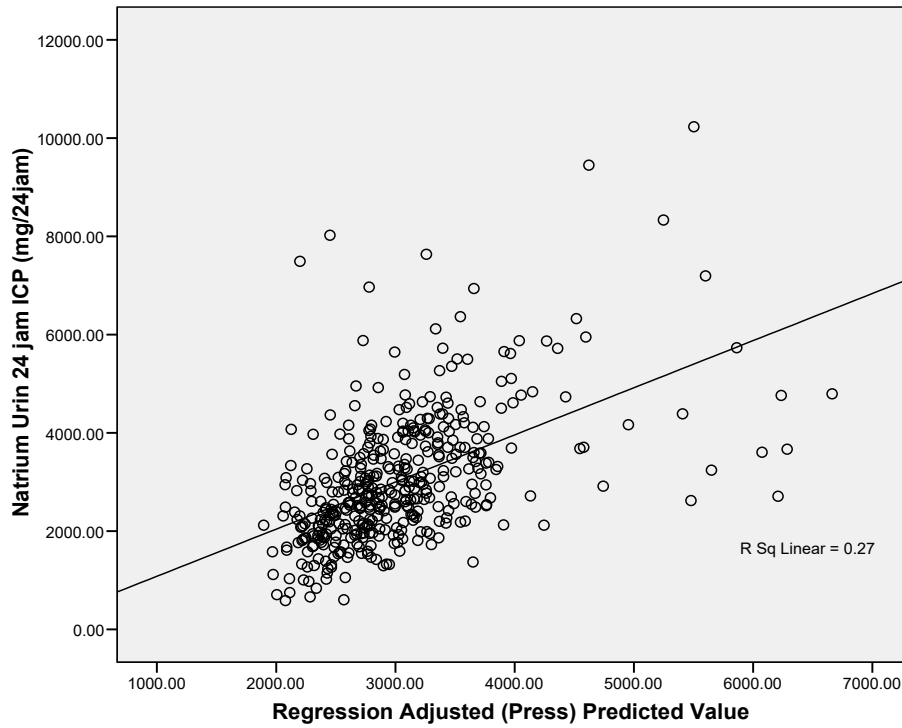


Figure 1. Linear Regression of Estimating 24 hours Sodium Urine Based on Morning Spot Urine Corrected by Creatinine Urine (Na/K US x K24hrs) Measured by ICP Lab (N=423)

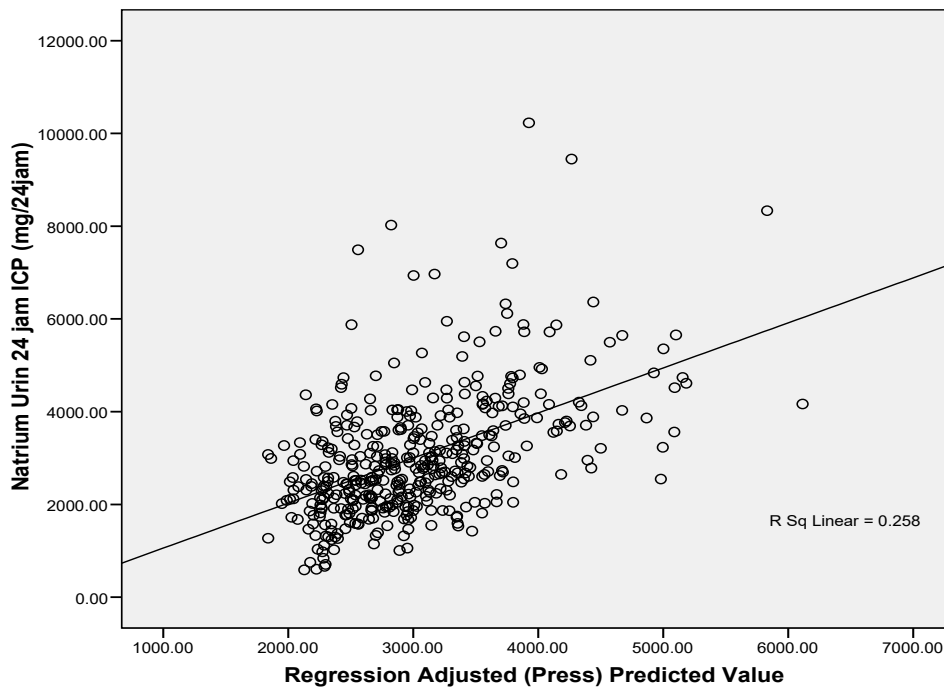


Figure 2. Linear Regression of Estimating 24 hours Sodium Urine Based on Morning Spot Urine by ICP Laboratory Test (N=423)

Table 5. Statistical of Residual Analysis of ICP 24 hours sodium urin (mg/24hours)

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	1,895.9977	6,062.0103	2,979.3314	664.02585	625
Std. Predicted Value	-1.631	4.642	0.000	1.000	625
Standard Error of Predicted Value	48.762	234.341	90.441	27.555	625
Adjusted Predicted Value	1,900.5605	6,139.6548	2,979.6354	664.40623	625
Residual	-2,754.36182	10,330.99512	0.00000	1,178.89520	625
Std. Residual	-2.331	8.742	0.000	0.998	625
Stud. Residual	-2.352	8.758	0.000	1.001	625
Deleted Residual	-2,805.26758	10,369.12891	-0.30399	1,186.92561	625
Stud. Deleted Residual	-2.361	9.348	0.002	1.013	625
Mahal. Distance	0.064	23.540	2.995	2.720	625
Cook's Distance	0.000	0.071	0.002	0.006	625
Centered Leverage Value	0.000	0.038	0.005	0.004	625

a. Dependent Variable: Natrium Urine 24 hours ICP (mg/24 hours).

4. Discussion

This study indicates that spot urine examination is valid to be conducted for the 24 hours urine estimation of sodium intake measurement using the regression formula that include weight, height (BMI) and age in small city that most likely describe a specific semi urban Indonesian population that geographically close to the capital city (approximately 53 km). Similar concept with other studies from different countries, the formula simply valid for the aggregated data not for individual diagnose of sodium intake (Xu et al., 2020). A spot urine measurement has been developed in many countries as an alternative for more feasible method to estimate the 24 hours sodium urine test for population.

Previous study in Japan, by Tanaka, shows regression formulas in the following: (1) $PRCr \text{ (mg/day)} = -2.04 - \text{age} + 14.89 - \text{weight (kg)} + 16.14 - \text{height (cm)} - 2244.45$; (2) $\text{estimated 24HUNaV (mEq/day)} = 21.98 - XNa0.392$; (3) $\text{estimated 24HUKV (mEq/day)} = 7.59 - XK0.431$; where $PRCr$ = predicted value of 24HUCr, $SUNa$ = Na concentration in the spot voiding urine, SUK = K concentration in the spot voiding urine, $SUCr$ = creatinine concentration in the spot voiding urine, XNa (or XK) = $SUNa$ (or SUK)/ $SUCr$ — $PRCr$. (Tanaka et al., 2002) A study in South Korea, finds that sensitivity of formula in estimating the 24-hr-urine sodium was around 84.3%, while the Tanaka formula was 87.6% (Charlton et al., 2020; Koo et al., 2014).

Sodium (Na) is consumed from food either in the form of sodium chloride salt (NaCl), flavor enhancer (sodium glutamate), or preservative (Sodium benzoate, ~ bicarbonate, ~ carbonate). There are two main sources of salt in the diet, namely salt added during cooking, or at the table (salt, MSG, soy sauce), processed food including preserved food (salted fish, corned beef) and processed food factory products (biscuits, crackers, etc.) (Brown, Tzoulaki, Candeias, & Elliott, 2009). Salt consumption about 5000 years ago before the Chinese people found a way to preserve food with salt of about 0.25 grams equivalent to 500 grams of sodium (He & MacGregor, 2009).

Role of food industry in individual salt intake is considered to be significant as it leads to salty food habituation. They use high salt content in the processed food to meet the consumer's preference. The food industry mostly shows resistancy in reducing salt content of processed food. In fact, experience in UK showed that lowering salt content in processed food did not cause sales reduction (He & MacGregor, 2009). In Indonesia, sources of consumption of sodium foods come mainly from salt and processed foods (instant noodles, crackers), preserved foods (salted fish), seasonings (soy sauce) and flavor enhancers (monosodium/sodium glutamate, MSG). Salt is the largest contributor of sodium intake, accounted to 62.43% (Kementerian Kesehatan, 2014).

Sodium is presented in intra- and intercellular. Sodium along with potassium (K) is an important element in maintaining cellular homeostasis, maintaining the balance of osmotic pressure and the distribution of body fluids so that nutrients, hormones, enzymes can come out and enter the cell. Normal level of sodium in blood plasma is between 136–146 mEq Na/L. To maintain this level, sodium intake is needed between 90–250 mEq Na/day. Sodium concentrations are excreted through urine as much as 80–180 mEq NA/day and can reflect sodium

intake (Pohl HR, Wheeler JS, 2013). But sodium values in both urine and blood are influenced by individual sensitivity and habits. The value of urinary sodium can be increased due to excessive consumption of salt, consumption of diuretics, kidney inflammation, decreased function of the adrenal glands, consumption of drugs (corticosteroids, anti-inflammatory steroids, prostaglandins (peptic ulcer drugs, glaucoma), neurologic disorders, and certain antibiotics. The value of urinary sodium can be decreased due to hyper-aldosteronism, dehydration, diarrhea, heart / kidney failure, CKD, liver cirrhosis, and hypothyroidism (*Sodium urine test_ MedlinePlus Medical Encyclopedia*, n.d.).

It is crucial for a country to identify the magnitude of sodium intake figure for nationwide population coverage, as a baseline to develop more effective health intervention which are based on the necessity for particular population characteristics such as gender and age group or geographical areas. Applying the valid formula from sodium spot urine to estimate the 24 hours sodium urine within the nationwide population based survey will be less costly and more feasible in term of minimizing bias in urine collection method. Another study showed that urine spot sample might provide accurate estimates of the 24-h sodium excretion in children at a population level (Text, 2019). Several research questions need to be addressed in the future research include which sodium spot urine test device that provide more valid results in comparison to the ICP method; how is the sodium intake variation across different social economy, cultural, dietary habit, and geographical settings of population and whether same estimation formula can be applied.

4.1 Limitations

This study has limitations such as the analysis had not yet include the contribution of dietary habit towards the sodium intake; the results may valid only for the studied population settings (aged 25-64 years), and did not include different population settings or geographical areas (urban-rural, or accross provinces) for comparison; younger age group was not included (such as for adolescenst group).

5. Conclusions

There is a moderate, positive, linear relationship between sodium urine estimation at morning spot based on ICP examination with 24 hours (examination) urine sodium spot. The morning spot urine examination is valid to be conducted for the 24 hours urine estimation of sodium intake. Moderate correlations are observed, convenience, and low cost and hence can be considered in the use of the urine pot method to examine sodium excretion, given the least effort in monitoring of sodium intake.

Competing Interests Statement

The authors declare that there are no competing or potential conflicts of interest.

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