SODIUM INTAKE IN MALAYSIAN ADULTS: VALIDATION OF ESTIMATIONS BY DIETARY AND SPOT URINE EXCRETION METHODS VERSUS 24-HOUR URINE EXCRETION

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ABSTRACT

Introduction: There are several methods available for assessment of sodium intake, including dietary and urinary excretion, which are fraught with methodological difficulties. Therefore, the aim of this study was to validate dietary and urinary excretion methods against 24-hour urinary excretion method in estimating sodium intake in Malaysian adults. **Methods:** A cross-sectional study has been carried out between November to December 2015. About 1568 adults aged 18 to 59 years old have participated from

16 study sites located in the 13 states and two federal territories of Malaysia. The study collected basic socio-demographic data and habitual dietary intake by Food Frequency Questionnaire (FFQ). Respondents were also asked to complete a two-day food intake diary (2FD) and collect their 24-hours urine and spot urine using standard protocols. **Results:** A total of 1116 adults successfully completed the survey, yielding a response rate of 71%. Sodium intake from 24-hour urine excretion was estimated at 2585.9mg/day which is above the recommendation by World Health Organization (WHO). The 2FD showed the nearest mean estimate to the reference method but the spot urine with Tanaka's predictive equation showed the least bias. The estimation of sodium from spot urine alone or with Kawasaki's predictive equation and FFQ method showed poor mean estimates and a large bias compared to the reference method. **Conclusions:** The 2FD and spot urine with Tanaka's prediction equation can be good alternatives for estimating daily sodium intake at the population level but not at the individual level.

KEYWORDS: Sodium intake validation, urine excretion, dietary sodium, Malaysia

INTRODUCTION

Sodium (Na) intake is recognized as a public health concern. Elevated or high sodium intake has been associated with several types of non-communicable diseases (NCDs), such as hypertension, cardiovascular disease (CVD), stroke and being overweight. Meanwhile, decreased or low sodium intake may reduce blood pressure and the risk of associated NCDs. (Bibbins-Domingo et al. 2010; WHO 2012 & Song et al. 2013).

Recent publications on sodium intake from World Health Organization (WHO) stated that populations around the world are consuming much more sodium than is physiologically necessary (WHO 2012; Elliot & Brown 2006). The majority are consuming more than the current WHO recommendation on sodium consumption for adults, which is 2,000mg sodium/day; equivalent to 5g salt/day (WHO 2007). Recent evidence estimated that the global average level of sodium consumption is 3.95g/day which is almost double the amount recommended by the WHO (Mozaffarian et al. 2014).

In this country, the latest Malaysian Adult Nutrition Survey (MANS) conducted in 2014 reported median sodium intake of Malaysian adults by 24-hour dietary recall method to be 1935mg sodium/day (IPH 2014), i.e., less than the WHO recommendation. However, the same survey also reported that 47.5% of the adult population were consuming more than 2000 mg per/day. Furthermore, the proportion of high sodium consumption was higher in males compared to females and in urban compared to rural localities (IPH 2014).

There are several methods available for assessment of sodium intake, including dietary and urinary excretion, which are fraught with methodological difficulties (Charlton et al. 2008). Most dietary methods such as single or multiple food diary, 24-hour diet recall and Food Frequency Questionnaire (FFQ) tend to underestimate results for sodium intake due to under-reporting in food consumption (Reinivuo et al. 2006). Meanwhile, the 24-hour urine collection method, considered as the 'gold standard', is burdensome and has a high potential for under collection of the 24-hours urine output (McLean 2014). Due to difficulties in 24-hour collection, the spot urine sample method was introduced as an alternative. However, the use of spot urine for monitoring sodium intake in epidemiological research remains controversial due to lack of substantial evidence on its reliability (Rhree et a;. 2014; Kelly et al. 2015).

The aim of this study was to validate dietary and urinary excretion methods in estimating sodium intake among Malaysian adults. The dietary methods were two days food intake diary (2FD) and Food Frequency Questionnaire (FFQ). Urinary excretion method was morning spot urine. The reference method was 24-hours urine collection.

METHODS

Study Design and Recruitment of Respondent

This cross-sectional study was conducted between November to December 2015. In total, 1568 adults aged 18 to 59 years old were randomly selected from 16 study sites located in 13 states and 2 federal territories of Malaysia. Exclusions were pregnant women, those who began diuretics therapy in

the last two weeks, had kidney disease and any condition that limited their ability to collect 24-hour urine. Permission to conduct this study was sought from the Medical Research Ethics Committee (MREC), Ministry of Health. Signed informed consent was obtained from each respondent before data and samples were collected.

Socio-demographic Characteristic and Health Status

Standard forms were designed with Optical Mark Recognition (OMR) to gain the data for socio-demographic and health status of the respondent. The socio-demographic data included gender, age, ethnicity, education status and marital status. Data on health status collected were Body Mass Index (BMI), Waist Circumference (WC), Blood Pressure (BP), hypertension status and diabetes status.

Two days Food Intake Diary (2FD)

A booklet type form for two days food intake diary was prepared for respondents to write down all the food that they consumed. The respondents recorded in their diaries the food that they consumed in two days which included one day during a weekday and one day during the weekend. They were instructed to record detailed information about their food including the time, name of the food, description about the food, especially the ingredients, and the quantity of food consumed from early morning after they woke from sleep until night before they slept. The food records were verified by a nutritionist/dietitian before they were sent to the operational room for data entry.

Food Frequency Questionnaire (FFQ)

The Food Frequency Questionnaire (FFQ) for estimating sodium intake was developed in a Sodium Intake Study 2012 conducted previously using 24-hour diet recall data (Rashidah et al., 2014). All food items consumed in the 24-hour diet recall in 2012 were extracted and listed with the proportion of intake. Foods that were consumed by more than 5% of the population and containing high sodium were shortlisted. Finally, 94 high sodium foods were included in the FFQ for estimating sodium intake. This FFQ was self-administered by respondents and subsequently verified by trained nutritionist/dietitians. In this FFQ, respondents filled up all the 94 food items in terms of their frequency of intake either daily, weekly or monthly basis and the amount of serving they consumed during each time they ate the food. If the respondent did not consume the food on a monthly basis, they answered '0' in the per/month column. Estimated sodium intake was calculated by multiplying the sodium content per serving with number of servings taken per day.

24-Hour Urine Collection

All respondents were provided with plastic cups and a 2.5 liter collapsible urine container for 24-hour urine collection. On the scheduled date, the respondents collected their urine from the second urine of that day until the first voided urine the following day. They recorded every time they collected the urine and they had to be frank in reporting if they had missed or forgotten to collect the urine that day. Respondents who failed to collect urine during the scheduled time or whose 24-hour urine collection was less than 500 millilitres were reminded and asked to do or redo the urine collection before the end of the data collection period.

Spot Urine

Spot urine was collected the subsequent morning after completing the 24-hour urine. A 1.5 liter anti-leak zip-lock bag was provided to the respondent for this purpose. The respondents submitted their 24-hour urine and spot urine to the liaison officer in every study site before the officer sent the samples to the nearest appointed private laboratory for analysis.

Data Analysis

NutritionPro Software was used to estimate sodium intake from the dietary methods. The Malaysian Food Composition Table was used as the main reference database for determining sodium content of each food consumed. In the case where the food is not available in the Malaysian Food

Composition Table, other databases were used, such as the United States Department & Agriculture (USDA) standard reference database, Canadian Nutrient File, Food and Nutrient Database for dietary study. A market survey was also conducted to find the sodium content from the food labels for branded products. Standard procedure to determine sodium secretion via urinary excretion methods was used by appointed private laboratories. The Tanaka's and Kawasaki's equations were used to estimate 24-hours urinary sodium.

Tanaka's equation;

21.98 x XNa0.392 where XNa = SUNa/SUCR x PRCr

SUNa = Na concentration (mEq/L) in the spot urine

SUCr = Creatinine concentration (mg/dl) in the spot urine

PRCr = Predictive creatinine [assumes that 24-hour urinary creatinine excretion can be estimated from following formula, -2.04 x age (years) + 14.89 x weight (kg) + 16.14 x height (cm) – 2244.45.)

Kawasaki's equation;

16.3 x √ (spot Na/Spot Cr) x predicted 24-hour urinary Cr

Where predicted 24-hour urinary Cr

Men : -12.63 x age (years) + 15.12 x weight (kg) + 7.39 x height (cm) – 79.9

Women: -4.72 x age (years) + 8.58 x weight (kg) +5.09 x height (cm) – 74.5

The IBM SPSS Statistics for Windows, Version 20.0 was used for all statistical tests. Characteristics of respondents were tabled in percentages or means and standard deviations as appropriate. Paired t-test and Pearson correlations were carried out between sodium estimation from 2-day food intake diary, FFQ and spot urine with sodium secretion from 24-hours urine. Bland-Altman analysis was also applied in order to assess the agreement and systematic bias between these tested methods and the gold standard.

RESULTS

From the total 1568 selected respondents, 1116 or 71.2% of them successfully participated in the survey. The characteristics of the respondents are shown in Table 1. The majority of the respondents were females (60.1%), Malay (85.5%) and married (79.3%). More than half of the respondents were within the overweight (36.0%) or obese (25.3%) category of BMI and 57.8% had abdominal obesity by their waist circumference. For health status, about 4.4% and 8.8% of the respondents had diabetes and hypertension respectively. The average blood pressure measured during the data collection were 120.86mmHg for systolic and 76.81mmHg for diastolic blood pressures.

Results for sodium intake estimated from dietary and urinary secretion methods are summarized in Table 2. Mean of sodium intake from the reference methods which is 24-hours urine excretion was 2585.9mg/day. Meanwhile spot urine without applying prediction equation give lower estimation in sodium intake which is 2344.6mg/day. The mean estimation on sodium intake was hike when spot urine prediction equations applied. Dietary method give small mean difference with reference method, but the correlation was weak.

Bland-Altman plots for further interpretation of agreement between the dietary and spot urine methods with 24-hours urine excretion are shown in Figure 1. Sodium estimation from spot urine using Tanaka's equation showed good agreement with 24-hours urine excretion with little mean difference and smallest bias compared to other dietary or spot urine secretion methods. For dietary methods, 2FD showed better agreement as compared to FFQ. The 2FD showed the least mean difference with 24-hours

urine excretion. However, the bias of 2FD with the reference method was slightly larger than urinary method but still better than FFQ.

Table 1 Characteristics of the respondents

Characteristics		n	Percentage
Malaysia		1116	100
Zone - North		293	26.3
- South		210	18.8
- East Coast		218	19.5
- Central		265	23.7
- Sabah and Sarawak		130	11.6
Gender - Male		445	39.9
- Female		671	60.1
Age (years) - 20 – 29		248	22.2
- 30 – 39		493	44.2
- 40 and above		375	33.6
Ethnicity - Malay		954	85.5
- Chinese		51	4.6
- Indian		30	2.7
- Bumiputera* Sabah		60	5.4
- Bumiputera* Sarawak		21	1.9
Education Status - Secondary and below		249	22.3
- Form 6**/ Diploma		451	40.4
- College/ University		406	36.4
Marital Status - Married		885	79.3
- Single		224	20.1
BMI (kg/m²) ¥ - <18.5 (Underweight)		46	4.0
- 18.5 – 24.9 (Normal)		397	35.6
- 25.0 – 29.9 (Overweight)		402	36.0
- ≥30.0 (Obese)		262	23.5
Waist Circum. (cm) ¥¥ - Normal		429	42.2
- Abdominal obesity		587	57.8
Health Status			
Diabetes	Yes	49	4.4
	No	1064	95.3
Hypertension	Yes	98	8.8
	No	1015	90.9
Blood Pressure			**Mean (sd)**
Systolic (mm/Hg)		1104	120.86 (17.31)
Diastolic (mm//Hg)		1104	76.81 (11.30)

¥ Classification of BMI according to World Health Organization (WHO) 1998
¥¥ Classification of waist circumference according to International Diabetes Federation (IDF) worldwide definition of metabolic syndrome (South Asians: Male ≥90 cm & Female ≥80 cm)
*Bumiputera – Indigenous people living in the area or state
**Form 6 – An education level after secondary school before entering university

Table 2 Mean sodium intake (mg/day) estimated from spot urine, FFQ and two days food record versus reference method of 24-hours urine collection

Instrument	Mean± SD	Median (IQR)	Range	Paired sample t-test			Paired sample correlation	
				Mean diff.	95% CI	*p*-value	r	*p*-value
24 Hours Urine Collection (reference)	2585.9±1095.1	2482.9	321.9 – 5896.9	-	-	-	-	-
Spot urine	2344.6±1331.5***	2184.0	459.8 – 6575.1	-257.7	-343.4, -171.9	0.001	0.372###	0.001
Spot urine (Tanaka's equation)	3089.3±803.2***	3049.0	166.7 – 6150.0	220.3	155.4, 285.2	0.001	0.644###	0.001
Spot urine (Kawasaki's equation)	3716.7±1264.9***	3709.6	91.1 – 9078.1	947.7	978.1, 1016.3	0.001	0.646###	0.001
Food Frequency Questionnaire (FFQ)	2915.2±1677.8***	2509.0	223.5 – 7822.9	348.7	226.6, 470.7	0.001	0.104###	0.001
Two days Food Record (2FD)	2660.0±881.9	2615.3	325.4 – 5172.6	81.4	-1.1, 163.9	0.053	0.152###	0.001

*p<0.05, ** p<0.01 and *** p<0.001

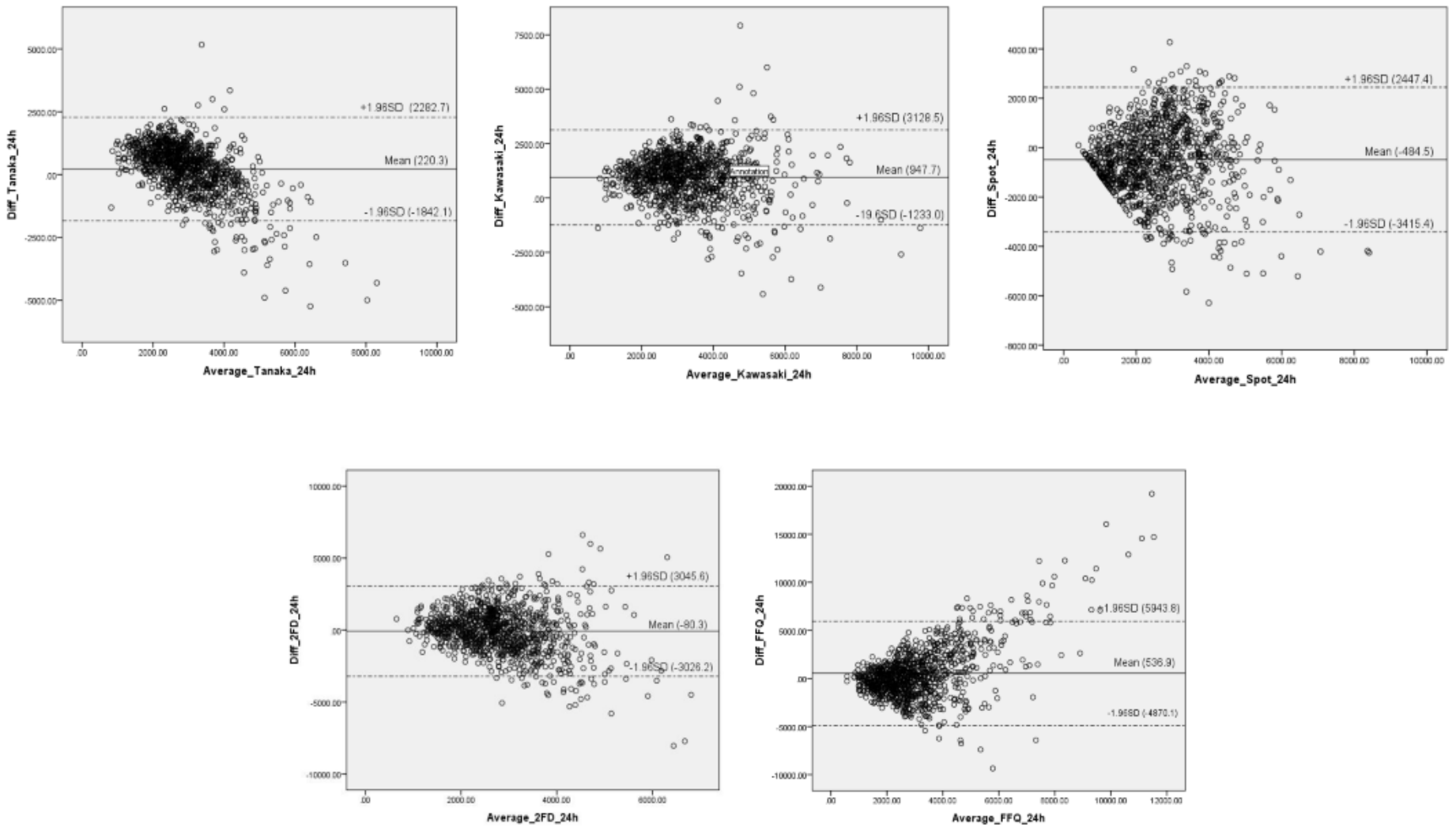

Figure 1 Bland-Altman analysis for dietary and spot urine excretion methods against the 24-hours urine collection method.

DISCUSSION

Estimation of sodium intake from the reference methods was 2585.9mg/day which is above the WHO recommendation (WHO 2007) and previous findings reported in a national survey (IPH 2014). The 2FD produced a mean estimated sodium intake closest to the reference method but the pair also showed weak correlation (r = 0.152). Spot urine without applying any equation tended to underestimate sodium intake. Spot urine by applying Tanaka's equation and Kawasaki's equation tended to overestimate the sodium intake. However, both sodium intakes estimated equations showed good correlation with the reference method. The FFQ was found to overestimate the sodium intake and also showed weak correlation with the reference method

The findings of this survey demonstrate that accuracy varies in estimating sodium intake by different methods. Spot urine without applying any prediction equation was not adequate to estimate sodium intake. These findings are consistent with an emerging consensus that spot urine is a poor predictor of daily sodium intake (Ji et al. 2012; Mc Lean 2014)

Meanwhile, spot urine with prediction equation, i.e., Tanaka's equation and Kawasaki's equation, overestimated sodium intake in our population. Previous surveys conducted among multi-ethnic populations in Britain and Italy also reported almost similar findings where the predictive equation tended to overestimate values at high levels of excretion (Ji et al. 2014). However, in our survey, Tanaka's equation gave more reliable data for sodium estimation than Kawasaki's equation.

For dietary methods, 2FD was found to be more reliable and valid in estimating daily sodium intake compared to FFQ. Although the FFQ was developed from a previous national food consumption survey, there is still a possibility that certain high sodium content food consumed by Malaysian adults were missed, especially new processed foods (Schaefer et al. 2000). The 2FD was believed to capture a complete daily food intake of individuals and gave more accurate data on nutrient intake (Day et al. 2001).

A major strength of this study was high numbers of respondents were successfully recruited. In addition, the respondent selection was representative of all Malaysian adults aged 18 to 59 years old in the country. Thus, the results on sodium intake are generalizable. On the other hand, a limitation of this study was not all markers for urine were analyzed, including potassium (K). Without potassium, the International Cooperative Study on Salt, Other Factors, and Blood Pressure (INTERSALT) predictive equation could not be applied.

CONCLUSION(S)

Despite its shortcomings, we conclude that the 2FD dietary method and urinary excretion method with Tanaka's prediction equation can be a good alternative in estimating daily sodium intake at the population level. Thus, it is recommended to create a Malaysian population prediction equation from spot urine rather than using other population prediction equations. There is no acceptable and practical alternative method to replace 24-hours urine collection for use in determining sodium intake at the individual level.

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REFERENCES

Bibbins-Domingo, K. Chertow, G.M. Coxson, P.G. Moran, A. Lightwood, J.M. Pletcher, M.J. and Goldman, L. (2010). Projected effect of dietary salt reductions on future cardiovascular disease. NEJM 362(7):590-599.

World Health Organization. (2012). Sodium intake for adults and children: guideline. Geneva: World Health Organization.

Song, H.J. Cho, Y.G. and Lee, H.J. (2013). Dietary sodium intake and prevalence of overweight in adults. Metabolism 62(5):703-708.

Elliot, P. and Brown, I. (2006). Sodium Intakes Around the World: Background Document Prepared for the Forum and Technical Meeting on Reducing Salt Intake in Populations. Geneva: World Health Organization.

World Health Organization. (2007). Prevention of cardiovascular disease: guidelines for assessment and management of cardiovascular risk. Geneva: World Health Organization.

Institute for Public Health. (2014). National Health And Morbidity Survey 2014: Malaysian Adult Nutrition Survey (MANS). Volume II – Survey Finding. MOH/S/IKU/45.15(RR).

Mozaffarian, D. Fahimi, S. Singh, G.M. Micha, R. Khatibzadeh, S. Engell, R.E. and Powles, J. (2014). Global sodium consumption and death from cardiovascular causes. NEJM 371(7):624-634.

Charlton, K.E. Steyn, K. Levitt, N.S. Jonathan, D. Zulu, J.V. and Nel, J.H. (2008). Development and validation of a short questionnaire to assess sodium intake. Public Health Nutr 11(1):83-94.

Reinivuo, H. Valsta, L.M. Laatikainen, T. Tuomilehto, J. and Pietinen, P. (2006). Sodium in the Finnish diet: II trends in dietary sodium intake and comparison between intake and 24-h excretion of sodium. Eur J Clin Nutr 60(10):1160-1167.

McLean, R.M. (2014). Measuring population sodium intake: a review of methods. Nutrients 6(11):4651-4662.

Rhee, M.Y. Kim, J.H. Shin, S.J. Gu, N. Nah, D.Y. Hong, K.S. and Sung, K.C. (2014). Estimation of 24-hour urinary sodium excretion using spot urine samples. Nutrients 6(6):2360-2375.

Kelly, C. Geaney, F. Fitzgerald, A.P. Browne, G.M. and Perry, I.J. (2015). Validation of diet and urinary excretion derived estimates of sodium excretion against 24-h urine excretion in a worksite sample. NMCD 25(8):771-779.

Rashidah, A. Yeo, P.S. Noor Ani, A. Muhammad Fadhli, M.Y. Tahir, A. Feisul Idzwan, M. Ahmad Ali, Z. Shuhaila, AG. Azli, B. Viola, M. Zainal, A.O. Ruhaya, S. and Madihah, M. (2014). Sodium Intake among Normotensive Health Staff Assessed by 24-Hour Urinary Excretion: A Cross-sectional Study. MJN 20(3).

IBM Corp. Released (2011). IBM SPSS Statistics for Windows, Version 20.0. Armonk, NY: IBM Corp.

Ji, C. Sykes, L. Paul, C. Dary, O. Legetic, B. Campbell, N.R. and Cappuccio, F.P. (2012). Systematic review of studies comparing 24-hour and spot urine collections for estimating population salt intake. Rev Panam Salud Publica 32(4):307-315.

Ji, C. Miller, M.A. Venezia, A. Strazzullo, P. and Cappuccio, F.P. (2014). Comparisons of spot vs 24-h urine samples for estimating population salt intake: validation study in two independent samples of adults in Britain and Italy. NMCD 24(2):140-147.

Schaefer, E.J. Augustin, J.L. Schaefer, M.M. Rasmussen, H. Ordovas, J.M. Dallal, G.E. and Dwyer, J.T. (2000). Lack of efficacy of a food-frequency questionnaire in assessing dietary macronutrient intakes in subjects consuming diets of known composition. The Am J Clin Nutr 71(3):746-751.

Day, N.E. McKeown, N. Wong, M.Y. Welch, A. and Bingham, S. (2001). Epidemiological assessment of diet: a comparison of a 7-day diary with a food frequency questionnaire using urinary markers of nitrogen, potassium and sodium. Int J Epidemiol 30(2):309-317.