# Dietary sources of sodium and Socio-demographics correlate of sodium intake in Brunei Darussalam using 24 hours urinary sodium excretion

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## ABSTRACT

**Introduction:** The aim of the study was to investigate sodium intake and identify sociodemographic correlates of sodium intake and major sources of sodium in the diet. **Materials and Methods:** A cross-sectional study of 172 conveniently sampled men and women. Dietary sodium was estimated from 24 hours urinary sodium excretion and dietary sources of sodium were determined using a food frequency questionnaire. **Results:** The mean sodium intake was 2,697 (SD 1,101) mg/day [salt equivalent 6.85 (SD 2.80) gm/day], with 71% exceeded the <2,000 mg sodium per day recommended by the World Health Organisation. The highest proportion of participants exceeded the recommendation were among males (84%; 95% CI: 72-95) and those in 18-29 age group (82%; 95% CI: 70-95). Using multivariable analysis, age and body weight were the main independent determinants of sodium intake. Salt and sauces added during cooking or at the table contributed to 61% while processed foods contributed to 39% of the total sodium intake. Noodle soup, plain soup, soy sauce, bread, chilli and tomato sauce were among the highest contributors of sodium. **Conclusions:** Sodium recommendation should be set at <2,000 mg per day. Intervention should put priority on consumers' education through mass media campaign with focused key messages to reduce discretionary salt and sauces in cooking or at table. Product reformulation of processed foods should be targeted at those with the largest contribution of sodium. Monitoring sodium reduction intervention and changes in population sodium intake is vital for the development of an effective policy and intervention on sodium.

**Keywords: Salt intake, urinary sodium excretion, dietary sources, sodium reduction strategy**

## INTRODUCTION

Excessive intake of sodium is associated with high blood pressure, [1] which increases the risk of cardiovascular disease. [1-3] In Brunei Darussalam, the prevalence of hypertension increased from 28.6% in 1997 to 33.8% in 2011. [4, 5] The World Health Organisation (WHO) has identified public health initiatives to reduce sodium intake as a priority and a highly cost-effective approach to combat non-

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communicable diseases; and recommends a maximum limit of sodium intake to <2,000 mg/day (salt equivalent <5 gm/day).[6, 7] In the United Kingdom, the sodium intake target is set slightly higher at <2,300 mg/day (salt <6 gm/day).[8]

Many countries around the world exceed the WHO recommended limit. Using a 24 hours dietary recall, the Malaysian Adult Nutrition Survey reported that the mean sodium intake was 2,575 mg/day.[9] In Thailand the population sodium intake was estimated to be approximately 3,264.5 mg/day, with 76.3% exceeding the WHO recommended limit.[10] However, dietary survey involving 24 hours dietary recall substantially underestimates sodium intakes. A 24 hours urinary sodium excretion has been regarded as the most reliable method and 'gold standard' to measure sodium intake.[6] However due to its high cost and heavy burden to participants, response rates were typically low. Using 24 hours urinary sodium excretion, the United Kingdom population sodium intake was estimated to be 3,175 mg/day.[11] The INTERMAP Study reported that Japan and China had among the highest sodium consumption, 4,561 mg/day and 5,233 mg/day respectively.[12] Survey using the gold standard in Singapore estimated that sodium intake was 3,265 mg/day, with the largest sources came from table salt and sauces, while in Malaysia estimated sodium intake was 3,429 mg/day.[13, 14]

There is a lack of data on sodium intake and it's dietary sources in Brunei Darussalam. Research on sodium intake is crucial to formulate effective public health policies and sodium reduction strategies. The aims of this study were to investigate sodium intake from 24 hours urinary sodium excretion, and to determine sociodemographic correlates of sodium intake, as well as to identify major dietary sources of sodium.

## MATERIALS AND METHODS

**Site:** Data collection was conducted in Brunei-Muara District in December 2014.

**Recruitment process:** Invitation letters and information sheets explaining nature and purpose of the study were circulated to Units and Divisions within the Ministry of Health. Potential participants who responded to the invitation were divided into eight groups and contacted via telephone to schedule a date for data collection and briefing on 24 hours urine collection.

**Inclusion and exclusion criteria:** Consenting individuals aged 20 years and above were eligible for the study. Females who were menstruating were not eligible to take part.

**Data collection:** The data collection comprised of three components; a physical examination, a self-administered questionnaire and a single 24 hours urine collection. The physical examination and questionnaires were completed on the day of data collection and the urine collection was scheduled within the following days.

**Physical examination:** Body weight and height were measured using a single calibrated electronic scale and stadiometer (WB3007301, Tanita Corporation, USA) to the nearest 0.1 kg and 0.1 cm respectively. Waist and hips circumference were measured using a standardised protocol[15] and blood pressure was measured using two validated electronic sphygmomanometers (HEM-907, Omron Corporation, Japan).

**Self-administered questionnaire:** The questionnaire comprised of sociodemographic, lifestyle and medical history and a semi-quantitative food frequency questionnaire (FFQ).

**Development of the Food Frequency Questionnaire:** The FFQ was designed to assess consumption of commonly consumed foods which contribute to substantial proportion of sodium in Brunei population diet. Inclusion of food items in the FFQ was determined based on secondary analysis of the National Health and Nutritional Status Survey (NHNSS) II raw data. All foods and beverages consumed by the NHNSS II survey adult population with their respective sodium content were extracted and categorised into 92 food groups. Percentage contribution of sodium from the food group was calculated by dividing the total sodium content in the food group by total sodium content of all foods, multiplied by 100 (Figure 1).

Food groups contributing to >0.5% of the survey population sodium intake were included. Of 92 food groups, 42 were included in the FFQ. The FFQ was further developed to assess frequency of intake over the past 12 months. Fifteen frequency category options were allocated for each food group, ranged from '4 times a day' to 'never'.

**Sodium Scoring System:** A scoring system was devised for the FFQ. Each food item or group was computed with a specific amount of sodium (mg). This amount was derived from the mean sodium content of foods in the food group consumed by the survey population in the NHNSS II. Weekly and monthly frequency categories were converted to daily frequency by dividing by seven and 30 respectively. Estimated daily sodium intake from food item in the FFQ was computed as daily frequency multiplied by the mean sodium content of the food.

**24 hours urinary sodium excretion:** Each participant was provided with a three-litre capacity screw cap container to serve as the collection containers for urine. A single 24 hours urine collection was obtained with the first urine voided upon awakening on the collection day being discarded. Participants collected all voided urine thereafter and ended with their first void the following day. Participants were instructed to record date and time of the first and last urine collection. Participants were instructed not to modify their dietary habits during the urine collection period. Completed urine collections were sent to an accredited hospital-based laboratory. Each participant was given a $10 shopping voucher for their participation in the study.

**Urine analysis laboratory procedure:** The total volume of urine collection was recorded and the sample was aliquoted into 5 ml sterile labelled container. Analysis of sodium was performed using ion selective electrodes on the Abbott Architect Ci8200 analyser. Electrical potential (voltage) was compared to previously determined calibrator voltages and converted into ion concentration (mmol/l). The reportable range of urinary sodium concentration was between 20 to 400 mmol/l. The imprecision for both between and within run was ≤3.0%. The 24 hours urinary sodium excretion was calculated as the product of total volume of urine collected (ml) and sodium concentration (mmol/l) divided by 1000 (Figure 2).

Suspected inaccurate urine collections including sample with <500 ml and extreme outliers were excluded. Taking into account that 5% of sodium is excreted through the skin and faeces, we multiplied the 24 hours sodium excretion with a factor of 100/95.[16] Daily sodium intake was estimated based on the assumption that all sodium ingested was in the form of sodium chloride. As in standard

$$\textit{Percentage contribution of sodium from food group (\%)} = \frac{\textit{Total sodium content in food group (mg)}}{\textit{Total sodium content in all food (mg)}} \times 100$$

**Fig. 1: Formula for calculating percentage (%) contribution for sodium from food groups.**

$$\textit{24 hours sodium excretion (mmol / day)} = \frac{\textit{24 hours urine (ml) x Sodium concentration (mmol / L)}}{1000}$$

**Fig. 2: Formula for calculating 24 hours sodium excretion.**

conversion, 1 gm salt was estimated to be 17.1 mmol sodium or 393.4 mg sodium. [17] The present study was conducted in accordance to the guidelines laid down in the Declaration of Helsinki and all procedures were approved by the Medical and Health Research Ethics Committee, Brunei Darussalam.

**Statistical Analysis:** Results were expressed as mean (SD). Independent t test was used to compare continuous variables. Descriptive statistics were used to calculate the mean 24 hours urinary sodium excretion and the prevalence of participants exceeded the WHO (2007) sodium recommended limit with 95% confidence intervals overall and by sociodemographic characteristic. Regression models were fitted to explore possible association between 24 hours urinary sodium excretion and a range of variables. Multiple linear regressions, including all selected sociodemographic variables in the model, were performed using stepwise and backward elimination. Statistical analysis was performed using SPSS version 22.0. [18]

## RESULTS

Sociodemographic characteristics of the participants are presented in Table 1. One hundred and seventy two individuals participated in the study. The mean age was 38.9 (SD 10.5) years, with females accounted for majority (70%) of the sample. The mean systolic and diastolic blood pressure was 127 (SD 17.8) mmHg and 75 (SD 11.2) mmHg respectively.

***24 hours urinary sodium excretion and proportion of participants exceeding recommended levels:*** of 172, four did not return their urine samples. Results from 17 urine samples were excluded; 15 contained <500 ml and two were outliers while the results from two participants were untraceable. Table 2 shows the mean 24 hours urinary sodium excretion and proportion exceeding the recommended sodium intake, using two different sodium limits.

The mean 24 hours urinary sodium excretion was 2,697 (SD 1,101) mg/day [salt equivalent 6.85 (SD 2.80) gm/day]. The urinary sodium excretion was higher in males, 3,069 (SD 1,234) mg/day [salt 7.80 (SD 3.14) gm/day] compared to females, 2,546 (SD 1,009) mg/day [salt 6.47 (SD 2.57) gm/day]. The urinary sodium excretion among the youngest age group (18-29 years) was about 1.3 times higher, 2,940 (SD 1,151) mg/day [salt 7.47 (SD 2.93) gm/day] than that of the older age group (≥50 years old), 2240 (SD 1,212) [salt 5.70 (SD 3.08) gm/day]. The prevalence of individuals exceeded the <2,000 mg/day and <2,300 mg/day recommended sodium limit was 71% (95% CI: 63-78) and 62% (95% CI: 54-70) respectively. More males [84% (95% CI: 72-95)] compared to females [65% (95% CI: 56-74)] exceeded the <2,000 mg/day sodium limit. By age group, there appears to be a decreasing trend, with the highest prevalence in the 18-29 age group [82% (95% CI: 70-95)] and the lowest in the ≥50 age group [49% (95% CI: 31-67)].

***Sociodemographic correlates of urinary sodium excretion:*** There was a significantly inverse relationship between urinary sodium excretion and age ($p$=0.016) and a significantly positive association between uri-

**Table 1: Characteristics of the study population.**

| Variables | Overall (*N*=172) |
|---|---|
| Age, years (mean) | 38.9 (10.5) |
| Male (%) | 29.7 |
| Weight, kg (mean) | 69.7 (15.6) |
| Height, m (mean) | 1.56 (0.08) |
| BMI, kg/m$^2$ (mean) | 28.5 (6.0) |
| Waist, cm (mean) | 88.7 (13.0) |
| Hips, cm (mean) | 102.1 (11.3) |
| Systolic blood pressure, mmHg (mean) | 127 (17.8) |
| Diastolic blood pressure, mmHg (mean) | 75 (11.2) |
| Age group (%) | |
| 18-29 | 25.6 |
| 30-39 | 26.7 |
| 40-49 | 26.7 |
| ≥50 | 20.9 |
| Ethnic group (%) | |
| Malay | 90.7 |
| Chinese | 4.1 |
| Other ethnic Brunei Malay | 4.1 |
| Others | 1.2 |
| Marital status (%) | |
| Single | 32.0 |
| Married | 63.4 |
| Widow/widower/divorcee | 4.7 |
| Education (%) | |
| Primary | 3.5 |
| Secondary | 47.1 |
| Tertiary (A Level, Vocational or Technical) | 23.8 |
| Graduate and postgraduate | 25.6 |
| Household income (%) | |
| <B$2,000 | 29.4 |
| B$2,000-$4,000 | 33.5 |
| B$4,001-$6,000 | 19.4 |
| >B$6,000 | 17.6 |
| Prescription medication use (%) | |
| Antihypertensive | 22.8 |
| Lipid lowering | 21.6 |
| Oral hypoglycaemic agent or insulin injection | 6.4 |
| Any prescription medication | 21.6 |

nary sodium excretion and weight ($p$=0.010) and height ($p$=0.014). Analysis of age and weight interaction revealed a non-significant finding. After adjusting for confounding variables, the urinary sodium excretion was only found to be significantly associated with age ($p$=0.017) and weight ($p$=0.011). For every one year increment in age, urinary sodium excretion decreased by 19.9 mg/day (95% 36.2, -3.55) and for every one kilogram increase in weight, urinary sodium excretion increased by 14.3 mg/day (95% CI: 3.35, 25.3). Other variables including gender, education level, race, BMI, waist circumference, waist and hips ratio, systolic and diastolic blood pressure, diabetes status, smoking status and duration of weekly physical exercise did not have any significant relationship with the urinary sodium excretion.

***Contribution of food to salt intake:*** Salt and sauces contributed to 61% of the total sodium intake, with the highest sources of sodium from discretionary salt added during cooking (43.1%), soy sauce (7.5%) and chilli and tomato sauces (5.2%) added at the table. There were 16 different types of cooked dishes with discretionary salt added at table (5.2%) and these were included in the discretionary salt in cooking group. Of these, the highest sources of sodium were from noodle soup, 27,822 mg (7.8%) and plain soup, 20,510 mg (5.7%). Processed foods contributed to 39% of the total sodium intake, with four highest sources of sodium from bread (5.8%), crisps and snack (4.8%), instant noodle (4.7%) and canned and packet soup (4.7%).

***Behaviours:*** Majority (75.4%) reported adding salt and sauces including soy sauce, chilli and tomato sauce at the table twice a week or more. The mean weekly intake of discretionary chilli and tomato sauce at the table was higher [2.9 (SD 3.09) times/week] than that of discretionary salt at the table [2.0 (SD 4.10) times/week] and discretionary soy sauce at the table [1.3 (SD 3.43) times/week].

## DISCUSSION

The efficacy of reduced sodium intake in lowering blood pressure is well established. Strong evidence suggests that modest reductions in dietary sodium could substantially reduce cardiovascular events and medical

**Table 2: 24 hours urinary sodium excretion and proportion exceeding the recommended sodium intake.**

| | Mean mg/day (SD) *n*=149 | Proportion exceeding recommended limit (95% CI) | |
|---|---|---|---|
| | | <2,000 mg/day | <2,300 mg/day |
| Overall | 2,697 (1101) | 70.5 (63.1-77.9) | 61.7 (53.9-69.6) |
| Male | 3,069 (1234) | 83.7 (72.2-95.2) | 72.1 (58.1-86.1) |
| Female | 2,546 (1009) | 65.1 (55.9-74.3) | 57.6 (48.0-67.1) |
| Age group | | | |
| 18-29 | 2,940 (1151) | 82.1 (69.5-94.7) | 71.8 (57.0-86.6) |
| 30-39 | 2,742 (937) | 78.1 (64.8-91.3) | 65.9 (50.7-81.0) |
| 40-49 | 2,798 (1032) | 69.4 (53.6-85.3) | 61.1 (44.4-77.8) |
| ≥50 | 2,240 (1211) | 48.5 (30.5-66.5) | 45.5 (27.5-63.4) |
| Ethnic group | | | |
| Malay | 2,712 (1124) | 68.9 (61.0-76.8) | 62.2 (53.9-70.5) |
| Chinese | 2,712 (803) | - | 50.0 (-7.5-108) |
| Other ethnic Brunei Malay | 2,321 (1080) | 66.7 (12.5-121) | 50.0 (-7.5-107) |
| Others | 2,724 (599) | - | - |
| Marital status | | | |
| Single | 2,798 (1234) | 74.0 (61.4-86.6) | 62.0 (48.1-75.9) |
| Married | 2,672 (1038) | 68.5 (58.8-78.2) | 62.0 (51.9-72.1) |
| Widowed/widower/divorced | 2,294 (912) | 71.4 (26.3-117) | 57.1 (7.7-107) |
| Education | | | |
| Primary | 1,756 (1269) | 25.0 (-54.6-105) | 25.0 (-54.6-105) |
| Secondary | 2,664 (1161) | 64.7 (53.1-76.4) | 57.4 (45.3-69.4) |
| Tertiary (A Level, Vocational or Technical) | 2,793 (1195) | 73.7 (59.0-88.4) | 68.4 (52.9-83.9) |
| Graduate and postgraduate | 2,756 (849) | 82.1 (69.5-94.7) | 66.7 (51.2-82.2) |
| Household monthly income | | | |
| <B$2,000 | 2,419 (1084) | 62.8 (47.7-77.8) | 53.5 (38.0-69.0) |
| B$2,000-$4,000 | 2,925 (1066) | 77.6 (65.4-89.7) | 71.4 (58.3-84.5) |
| B$4,001-$6,000 | 2,810 (1221) | 73.3 (56.5-90.1) | 63.3 (45.0-81.6) |
| >B$6,000 | 2,557 (993) | 65.4 (45.8-85.0) | 53.9 (33.3-74.4) |

costs. [1-3, 19, 20] In view of the increasing prevalence of raised blood pressure in Brunei Darussalam, baseline information on sodium intake and dietary sources of sodium is crucial to formulate effective public health policies and recommendations on sodium.

Our study provides for the first time sodium intake of a subgroup population in Brunei Darussalam. The mean sodium intake derived from 24 hours urinary sodium excretion was 2,697 mg/day (salt equivalent 6.9 gm/day), lower than that reported in Malaysia and Singapore. [13, 14] Male participants in our study had higher sodium intake compared to their female counterparts. This is consistent with the previous studies, [9-11, 14] reflecting higher calorie intake among males. [21, 22] Our results revealed that age and weight were independent determinants of sodium intake, suggesting a decreasing sodium intake with increasing age, and an increasing sodium intake with increasing body weight. It is possible that both age and body weight, is a reflection sodium intake compared to their female counterparts. This is consistent with the previous studies, [9-11, 14] reflecting higher calorie intake among males. [21, 22] Our results revealed that

**Table 3: Sociodemographic correlates of 24 hours urinary sodium excretion using simple and multiple linear regressions.**

| | Simple Linear Regression | | | Multiple Linear Regression[a] | | | |
|---|---|---|---|---|---|---|---|
| | *b*[b] | (95% CI) | *p* value | *Adj.b*[c] | (95% CI) | *t*-stat. | *p* value |
| Age (years) | -20.6 | (-37.2, -3.96) | 0.016 | -19.9 | (-36.2, -3.55) | -2.41 | 0.017 |
| Weight (kg) | 14.8 | (3.63, 25.9) | 0.010 | 14.3 | (3.35, 25.3) | 2.58 | 0.011 |
| Height (m) | 2,697 | (552, 4843) | 0.014 | - | - | - | - |

**Table 4: Percentage contribution of foods to sodium intake.**

| | Sodium intake (mg) | Percentage contribution (%) |
|---|---|---|
| Salt and sauces | | 61 |
| Discretionary salt in cooking | 154,196 | 43.1 |
| Soy sauce added at table | 26,719 | 7.5 |
| Chilli and tomato sauce added at table | 18,641 | 5.2 |
| stock cube and powder | 15,617 | 4.4 |
| Sambal and shrimp paste | 2,501 | 0.7 |
| Western sauce | 554 | 0.2 |
| Processed food | | 39 |
| Bread | 20,754 | 5.8 |
| Crisps and extruded snack | 17,012 | 4.8 |
| Instant noodle | 16,763 | 4.7 |
| Canned and packet soup | 16,651 | 4.7 |
| Frankfurter | 10,964 | 3.1 |
| Soybean milk | 8,760 | 2.5 |
| Chicken nugget | 7,771 | 2.2 |
| Fast foods | 13,611 | 3.8 |
| Dried prawn and anchovies | 6,883 | 1.9 |
| Preserved food | 4,370 | 1.2 |
| Canned food | 4,513 | 1.3 |
| Sushimi | 4,064 | 1.1 |
| Cheese | 3,290 | 0.9 |
| Salted egg | 1,371 | 0.4 |
| Salted seeds and nuts | 1,171 | 0.3 |
| Salted fish | 1,109 | 0.3 |

**Table 5: Mean weekly intake in the three frequency categories.**

| | Mean times/ week (SD) | Percentage (%) | | |
|---|---|---|---|---|
| | | ≥ 6 times week | 2-5 times a week | ≤ 1 time week |
| Salt and sauces | | | | |
| Discretionary salt and sauces at table | 6.12 (6.89) | 42.5 | 32.9 | 24.6 |
| Discretionary salt at table | 2.03 (4.10) | 20.2 | 4.2 | 75.6 |
| Discretionary soy sauce at table | 1.34 (3.43) | 7.6 | 14.1 | 78.2 |
| Discretionary chilli or tomato sauce at table | 2.90 (3.09) | 18.8 | 40.0 | 41.2 |
| Noodle soup | 0.68 (1.79) | 2.3 | 7.0 | 90.6 |
| Plain soup | 1.06 (2.13) | 4.1 | 19.4 | 76.5 |
| Processed food | | | | |
| Bread | 3.48 (3.67) | 18.1 | 49.1 | 32.7 |
| Crisps and extruded snack | 1.75 (2.82) | 5.8 | 32.7 | 61.4 |
| Instant noodle | 1.00 (1.31) | 1.8 | 21.1 | 77.2 |
| Canned or packet soup | 0.45 (0.94) | 0.6 | 8.2 | 91.2 |
| Eating out | 7.16 (7.07) | 45.9 | 30.0 | 24.1 |
| Fast food restaurants | 0.90 (1.85) | 2.9 | 13.5 | 83.5 |

age and weight were independent determinants of sodium intake, suggesting a decreasing sodium intake with increasing age, and an increasing sodium intake with increasing body weight. It is possible that both age and body weight, is a reflection of total calorie and hence total sodium intake. About 70% of the study population exceeded the WHO sodium recommended limit. By comparison, 80% and 76% of adults in Singapore and Thailand exceeded the sodium recommended limit respectively. [10, 14] Similar to the cross-sectional trend in the mean sodium intake, the prevalence exceeded the sodium recommended limit were high among males, 18-29 years of age, singles, those with higher education level and those with household monthly income between B$2,000-B$4,000. Based on these findings, sodium target in Brunei Darussalam should be set at <2,000 mg/day. Implementation of population-wide sodium reduction programme should include strategy that specifically targets the subgroup populations with high sodium intake and the strategy should take into account specific needs and characters of these subgroup populations.

In Asia, discretionary use of salt and sauces in cooking and at table accounts for majority of the total sodium intake which ranged from 60% to 85.3%. [12, 23] In accordance, 61% of the total sodium intake in our study was from discretionary salt and sauces in cooking and at table, while the remaining 39% was from processed foods. By comparison, as much as 83% of sodium intake in western countries was derived from processed foods. [24] For this reason, product reformulation to reduce sodium content in processed foods in the industrialised countries is justifiable. In fact, active product reformulation has been coined as the primary contributor to the success of population-wide sodium reduction strategy in the United Kingdom. [25] Sensibly, population-wide sodium reduction efforts in Brunei Darussalam should put emphasis on consumer education through mass media campaign on discretionary salt and sauces added in cooking and at the table. The customer education needs to highlight major contributors of sodium in cooked dishes with added discretionary salt such as plain soup. Customary in Brunei Darussalam, many hawkers and restaurants routinely serve plain soups with main dishes. These soups tend to be prepared with a large amount of salt while protein or other micronutrients content are negligible. Noodle soup was also found to be an important vehicle of sodium. In Malaysia, a bowl of noodle soup may contain as much as 1,700 mg sodium (salt 4.3 gm), while in Singapore it may contain as much as 2,636 mg sodium (salt 6.7 gm). [23, 26]

Alarmingly, 75% reportedly added salt and sauces at table twice a week or more and the contribution of discretionary sauces at the table to the total sodium intake was substantial. The type of sauces that tend to be more frequently added at the table was in the form of chilli and tomato sauce (ketchup) compared to soy sauce and salt. Although due to the high density of sodium per serving, the latter two remained the higher contributors of sodium in diet. Discretionary salt and sauces added at table essentially represents modifiable individuals' dietary behaviour that may change over time and with education. Fundamentally an environment that gears toward facilitating the change needs to be established. Hawkers and restaurants play an important role in establishing an enabling environment, by voluntarily removing salt shakers, soy, chilli and tomato sauces from the table and to gradually reduce sodium in plain soup and noodle soup.

Processed food contributed to a lesser extent to the total sodium intake, with bread, crisps and extruded snack, instant noodle, canned and packet soup represent among the highest contributors of sodium in the processed food category. Frequency of processed foods intake such as crisps, extruded snack, instant noodle, canned and packet soup was relatively low. However, the fact that these foods contributed to substantial proportion of sodium in the diet, indicates the quantity consumed and/or the grossly sodium-dense content of these foods. In our earlier study, half of the processed foods in Brunei Darussalam had sodium content above the Healthier Choice Nutrient Guidelines. [27, 28] Conversely well-known sodium-dense foods such as salted egg or salted fish were consumed less frequently and in smaller portions, rendering these foods to be lower in the sodium contributor hierarchy. Given the fact that processed foods contributed to only 39% of the total sodium intake, it may still worth to explore the potential of product reformulation in reducing population sodium intake in Brunei Darussalam. However, as majority of food products in Brunei Darussalam are manufactured outside of the country, an effective sodium reduction strategy through product reformulation will need to involve engagement with multinational food manufacturers through various bilateral and regional cooperation mechanisms.

Our study is the first in Brunei Darussalam to use the gold standard 24 hours urinary sodium excretion to measure sodium intake. However, in interpreting our findings a number of limitations need to be considered. Owing to the time constraint, the sample size was relatively low hence it is possible that the statistical power is not strong enough to detect differences in sodium intake between subgroups. Our sampling approach was not based on a random community sample, resulting in a predominantly females study population. However, a study by Land *et al.*, evaluating the validity of 24 hours urinary sodium excretion using a random versus a volunteer sampling reported that the estimated sodium intake derived from the two samples was comparable and that volunteer sampling may give a fairly robust estimate of sodium intake. [29] Our self-administered FFQ has not been validated and may not adequately capture discretionary sodium added during cooking or at the table. The absence of portion size options indicates the assumption that our participants behave like the rest of the study population in the NHNSS II.

Our study highlighted priority for future public health action on sodium. Consumer education through mass media campaign should be strategically tailored and targeted towards the needs and character of subgroup population with high sodium intake. Work should be simultaneously carried out with hawkers and restaurants to voluntarily reduce salt in their soups and to remove salt shakers and condiments from the tables and product reformulation should target the highest sources of sodium in the diet.

In conclusion, our study provides important baseline information, highlights priority and recommendation for effective public health intervention on sodium. The mean sodium intake should not be taken as rooms for complacency, as majority of the study population exceeded the sodium recommended limit. Subgroups of population with high sodium intake and major dietary sources of sodium were identified. Continuous monitoring of future public health policies and/or intervention is fundamental in facilitating change of population sodium intake.

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