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Estimated dietary sodium intake in Thailand: A nationwide population survey with 24-hour urine collections

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Abstract

Thailand has committed to reducing population sodium intake by 30% by 2025. However, reliable nationally representative data are unavailable for monitoring progress toward the goal. We estimated dietary sodium consumption using 24-hour

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urinary analyses in a nationally representative, cross-sectional population-based survey. We selected 2388 adults (aged ≥ 18 years) from the North, South, North-east, Central Regions, and Bangkok, using multi-stage cluster sampling. Mean sodium excretion was inflated by 10% to adjust for non-urinary sources. Multivariate logistic regression was performed to assess factors associated with sodium consumption ≥ 2000 mg. Among 1599 (67%) who completed urine collection, mean age was 43 years, 53% were female, and 30% had hypertension. Mean dietary sodium intake (mg/day) was 3636 (±1722), highest in South (4108 ± 1677), and lowest in North-east (3316 ± 1608). Higher sodium consumption was independently associated with younger age (Adjusted Odds Ratio (AOR) 2.81; 95% Confidence interval (CI): 1.53-5.17; *p* = .001); higher education (AOR 1.79; 95% CI: 1.19-2.67; *p* = .005), BMI ≥ 25 (AOR 1.55; 95% CI: 1.09-2.21; *p*=.016), and hypertension (AOR 1.58; 95% CI: 1.02-2.44; *p* = .038). Urine potassium excretion was 1221 mg/day with little variation across Regions. Estimated dietary sodium consumption in Thai adults is nearly twice as high as recommended levels. These data provide a benchmark for future monitoring.

1 | INTRODUCTION

High intake of sodium was the leading dietary risk factor associated with 3 million deaths and 70 million disability-adjusted life-years (DALYs) lost in 2017, worldwide.[1] Excess sodium consumption is associated with raised blood pressure and increased cardiovascular risk and chronic kidney disease.[2,3] The World Health Organization recommends limiting daily sodium intake to less than 2000 mg to reduce the risk of hypertension and associated cardiovascular disease.[4]

Cardiovascular disease was responsible for an estimated 145 000 deaths or 29% of all deaths in Thailand in 2016.[5] Stroke and ischemic heart disease have consistently ranked as the top two causes of mortality in Thai population during the past decade.[6] Of concern, the prevalence of hypertension has steadily increased from 21% in 2003 to 25% in 2014.[7] Recognizing the high and rising burden of cardiovascular disease, the National Health Assembly in 2015 adopted a resolution committing to reduce sodium consumption in Thai population by 30% by 2025.[8] Subsequently, a multipronged national sodium reduction strategy was developed to achieve this goal.[9]

Regular monitoring with valid data is critical for tracking the progress in sodium reduction efforts. Available studies on sodium consumption in Thailand are not nationally representative in scope or have methodological limitations. One nationwide study used a 7-day dietary recall in combination with weighing household condiments and estimated the daily intake at 10.8 grams of salt (4320 mg sodium).[10] Another national-level survey using food frequency questionnaire found that daily sodium consumption varied from 2473 mg among children (aged 1-5 years) and 3265 mg per day among adults.[11] Both studies used indirect methods and are likely to underestimate sodium consumption.[12,13] Studies using 24-hour urinary analyses are considered to provide more accurate measurement of sodium intake.[14] Limited number of Thai studies has been conducted using 24-hour urine collections, and these were in a small sample of high-risk patients, unrepresentative and unreliable for a national benchmark.[15]

To provide robust data for monitoring the progress toward the national sodium reduction target, this study aims to estimate dietary sodium intake using 24-hour urine collection methodology from a representative nationally drawn sample. The study also describes variations in sodium intake by geographical regions and examines factors associated high sodium consumption.

2 | METHODS

2.1 | Study design and participants

This was a nationwide, population-based cross-sectional survey using 24-hour urine collections. The survey was conducted between April 2019 and May 2020. We included both urban and rural areas in four Regions of Thailand (North, South, North-east, Central) plus the Bangkok metropolitan area to represent the entire country. Study participants included adults aged 18 years and older who were eligible and provided informed consent. Participants were excluded if they: had a known history of end-stage renal disease; started diuretic within the previous 2 weeks; were pregnant, breastfeeding, or menstruating; refused to provide consent; used salt supplements, and sodium retaining medicines; or were on steroid therapy.

2.2 | Sampling and sample size

We calculated the sample size for estimating population mean using the software, N4stuides.[16] We assumed the standard deviation of sodium intake to be 3.8 g/d based on a previous report of an estimated variation of mean sodium intake in Thai population.[17] We used an effect size of 0.21 and significance level (alpha) of 0.05, to calculate the required sample size to be 250 for each of the eight strata, that is, men and women in four age groups (18-29, 30-44, 45-59, 60 and above).

To account for the possibility of 20 percent refusal to participate, we adjusted the total expected sample size to 2400.

There are 76 provinces in 13 Health Service Areas in 4 geographic Regions of Thailand. We used multi-stage stratified-cluster random sampling to select participants. First, in each of the four geographic Regions of Thailand, we randomly selected two to three provinces, one province from each Health Service Area. A total of 13 provinces and Bangkok metropolitan area were selected. Secondly, for each province, we randomly selected two districts, one urban and one rural. Thus, in total, 28 districts in 14 provinces were selected. Finally, patients in each sampled district were randomly selected from eight strata, stratified by sex and four age groups: 18-29, 30-44, 45-59, 60 and above. Updated population registries maintained by district health office were used for the sampling universe, and samples were proportionally drawn from each strata.

2.3 | Data collection

In each region, a multidisciplinary team was trained to collect demographic, anthropometric, and clinical data as well as 24-hour urine specimens from all consenting participants.

2.3.1 | Demographic and clinical data

A structured questionnaire was used to collect data on age, sex, occupation, education level and income, medical history, and current medication consumed.

2.3.2 | Physical measurements

Height was measured to the nearest 1 centimeter. Weight was measured using calibrated Tanita HD-380 portable electronic scales (USA) to the nearest 100 grams. Body mass index (BMI) was calculated by dividing weight in kilograms by height in meters squared (kg/m^2). Blood pressure was measured using a digital blood pressure device, Omron HEM-7130-L (Omron Healthcare). Participants were asked to rest for 15 minutes before measurement. Blood pressure was measured 3 times at 15-minute intervals. The first measurement was discarded, and an average of the last two readings was used. Hypertension was defined as anyone with systolic blood pressure ≥ 140 and or diastolic blood pressure ≥ 90 mm Hg or taking medication for hypertension.

2.3.3 | Urine Collection

Field researchers provided each participant with detailed verbal and written instructions using a pictorial guide. Each participant received a labeled sterile plastic container of 5-Liter capacity,

TABLE 1 Characteristics of study participants who did not complete 24-hour urine collection

Characteristics	Total number	Did not complete	
		Number	%
Overall	2388	789	33.0
Region**			
Bangkok	398	234	58.8
Central	496	172	34.7
North	496	164	33.1
Northeast	498	156	31.3
South	500	63	12.6
Area**			
Urban	1158	461	39.8
Rural	732	172	23.5
Sex**			
Male	1162	414	35.6
Female	1226	375	30.6
Age groups**			
18-29 years	571	198	34.7
30-44 years	606	170	28.1
45-59 years	655	201	30.7
60 years and above	554	218	39.4
Education level**			
Primary	828	305	36.8
Secondary and above	1484	458	30.9
Income (Thai baht per month)**			
Low (0-9,999)	1654	506	30.6
Medium (10,000-19,999)	466	187	40.1
High (20,000 and above)	181	66	36.5
Body mass index (Kg/m^2)**			
<18.5	205	104	50.7
18.5-24.9	1245	475	38.2
25 and above	868	187	21.5
Hypertension*			
Yes	695	221	31.8
No	1628	545	33.5
History of diabetes**			
Yes	195	83	42.6
No	2128	683	32.1
Marital status			
Married	1341	419	31.2
Single	672	243	36.2
Separate/Divorce/Other	309	103	33.3

*Hypertension was defined as anyone with systolic blood pressure ≥ 140 and or diastolic blood pressure ≥ 90 mm Hg or taking medication for hypertension.

**p-value < 0.05 when compared with participants who completed urine collection.

TABLE 2 Characteristics of participants who completed 24-hour urine collection, by Regions

Characteristics	Total N (%)	Bangkok N (%)	Central N (%)	North N (%)	Northeast N (%)	South N (%)	*p*-value
Overall	1599	164(10.3)	324(20.3)	332(20.8)	342(21.4)	437(27.3)	
Sex							.253
Female	851 (53.2)	88 (53.7)	186 (57.4)	181 (54.5)	181 (55.9)	215 (49.2)	
Region							**<.001**
Urban	849 (53.1)	164 (100)	165 (50.9)	151 (45.5)	152 (46.9)	217 (49.7)	
Age groups							**.014**
18-29 years	373 (23.3)	38 (23.2)	53 (16.4)	82 (24.7)	92 (28.4)	108 (24.7)	
30-44 years	436 (27.3)	52 (31.7)	93 (28.7)	89 (26.8)	95 (29.3)	107 (24.5)	
45-59 years	454 (28.4)	37 (22.6)	118 (36.4)	90 (27.1)	87 (26.9)	122 (27.9)	
60 years and above	336 (21)	37 (22.6)	60 (18.5)	71 (21.4)	68 (21)	100 (22.9)	
Education Level							**.004**
Secondary and above	1026 (66.2)	117 (71.3)	195 (60.2)	201 (60.5)	206 (63.6)	307 (70.2)	
Income (Thai baht per month)							**<.001**
Low (0-9999)	1148 (74.4)	88 (53.7)	219 (67.6)	284 (85.5)	233 (71.9)	324 (74.1)	
Medium (10 000-19 999)	279 (18.1)	52 (31.7)	79 (24.4)	37 (11.1)	29 (9)	82 (18.8)	
High (20 000 and above)	115 (7.5)	23 (14)	24 (7.4)	11 (3.3)	26 (8)	31 (7.1)	
Body mass index (Kg/m^2)							**.005**
<18.5	101 (6.5)	18 (11)	21 (6.5)	22 (6.6)	12 (3.7)	28 (6.4)	
18.5-24.9	770 (49.6)	97 (59.1)	159 (49.1)	151 (45.5)	155 (47.8)	208 (47.6)	
25 and above	681 (44.0)	49 (29.9)	144 (44.4)	159 (47.9)	128 (43.4)	201 (46)	
Hypertension*							**<.001**
Yes	474 (30.4)	48 (29.3)	113 (34.9)	111 (33.4)	60 (18.5)	142 (32.5)	
History of diabetes							.584
Yes	112 (7.2)	14 (8.5)	29 (9)	21 (6.3)	20 (6.7)	28 (6.4)	
Marital status							**.001**
Married	922 (59.2)	76 (46.3)	186 (57.4)	201 (60.5)	193(59.6)	266 (60.9)	
Single	429 (27.6)	63 (38.4)	77 (23.8)	94 (28.3)	75 (23.1)	120 (27.5)	
Separate/Divorce /Other	206 (13.2)	25 (15.2)	61 (18.8)	37 (11.1)	32 (9.9)	51 (11.7)	

*Hypertension was defined as anyone with systolic blood pressure ≥ 140 and or diastolic blood pressure ≥ 90 mm Hg or taking medication for hypertension. Bold significance are P-value <0.05.

measuring cups, a cooler box, and a time sheet for recording the time and volume of urine collection. On the morning of the collection day, participants were instructed to discard the first morning urine specimen after waking up. Participants were asked to note the exact time of the first collection, and each collection subsequently. Participants were asked to collect all urine specimens over the next 24 hours, starting with the second void and including the first void on the following day. Participants were instructed to store all urine specimens in the 5-Liter cooler box filled with ice and record the time and volume of urine at each void. In case of reported duration of collection of 1 void was missed, or if there was more than one episode of substantial spillage of a void, the collection was deemed incomplete and the participant was offered to redo the 24-hour collection.

2.4 | Processing of urine samples

Urine samples were collected by trained field researchers on the day of completion and transferred to the local laboratory for determination of urine volume, sodium, potassium, and creatinine excretion. The volume was standardized to 24-hour period as follows: (total volume collected in liters/self-reported collection time in hours) times 24 hours.

Urinary sodium and potassium were determined using the indirect ion-selective electrode method and the enzymatic method for urine creatinine assay. Urine samples were considered incomplete if (a) total urine volume was less than 500 ml in 24- hour collection; (b) estimated daily urinary creatinine excretion was less than 0.98 g/day for males and less than 0.72 g/day for females[18]; (c) reported duration of

TABLE 3 Weighted estimated 24-hour urinary electrolyte excretion, by Regions

	Total		Bangkok		Central
Parameter	Mean (SD)	Median (IQR)	Mean (SD)	Median (IQR)	Mean (SD)
Volume (ml)	1757.1 (954.6)	1530(1030-2330)	1416.8 (752.6)	1150 (855-1750)	1553.6 (899.9)
Urine creatinine excretion (mg/24h)	1285.7 (401.9)	1210.4 (993.6-1493.5)	1261.1 (445.8)	1145.1 (930.2-1495.9)	1323.9 (397.5)
Urine sodium (Na) excretion (mg/24h)	3305.1 (1565.6)	2992.8 (2252.4-4108)	3178.1 (1516.1)	2811.3 (2090-4097.7)	3417.9 (1539.6)
Urine potassium (K) excretion (mg/24h)	1220.5 (492.1)	1143.1 (869.2-1488.4)	1191 (514.2)	1099.6 (809.3-1505.4)	1159.4 (516.7)
Sodium creatinine ratio (Molar ratio)	1.3 (0.6)	1.2 (0.9-1.6)	1.3 (0.5)	1.2 (0.8-1.6)	1.3 (0.5)
Urine Na/K ratio (mmol/mmol)	5 (2.4)	4.5 (3.3-6.1)	4.7 (1.8)	4.5 (3.5-5.6)	5.5 (2.6)
Estimated sodium consumption	3636 (1722.2)	3292 (2477.6-4518.8)	3495.9 (1667.7)	3092.4 (2299-4507.4)	3759.7 (1693.6)
Salt intake (g/day)	9.1 (4.30)	8.23 (6.19-11.29	8.73 (4.15)	7.7 (5.4-11.3)	9.4 (4.2)

collection was less than 24 hours; (d) more than 1 void was reported as missed; or (e) there was > 1 episode of significant spillage of a void.

2.5 | Statistical analysis

We analyzed data with sample weighted against the Thai population registry 2019. Probability weights were the inverse of the calculated probability of sampling of individuals in each region, province, area of residence (urban/rural), sex, and 4 age groups. Weighted mean, standard deviation, 95% confidence interval (CI) of mean, and median and interquartile range (IQR) were calculated for continuous variables. We compared the weighted mean of sodium intake by sex, region, urban/rural residence, education level, and presence of hypertension or diabetes using t test, and ANOVA, as appropriate. Chi-square test and Fisher's exact test were used to compare categorical variables. Multivariate logistic regression analysis was performed to examine association between high sodium consumption (≥ 2000 mg per day) with sex, region, age groups, education level, occupation, marital status, family income, BMI, hypertension, and diabetes. Multivariate linear regression analysis was also performed to examine association between weighted mean of sodium consumption with the same variables as multivariate logistic regression. A two-side p-value < .05 was considered statistically significant. Adjusted odds ratio (AOR) and 95% CI were calculated. Statistical analysis was performed using Stata Corp Stata 15.1 v.2020.

2.6 | Ethical considerations

Participation in the survey was voluntary. Informed written or oral consent was obtained from all participants prior to enrollment. Each participant was offered a financial incentive of THB 500 (USD 15) to participate in the study. Upon completion of data collection, we assured confidentiality by striping personal identifiers from all records. The protocol was approved by the Ethics Committee of Ramathibodi Hospital, Mahidol University. (COA.No. MURA2018/588).

3 | RESULTS

3.1 | Population characteristics

Of 2400 sampled participants, 2388 consented to participate in the study and provided a 24-urine specimen. Among these, 1599 participants (67%) completed a 24-hour urine collection, significantly high proportion of participants who did not complete urine collection in Bangkok (59%); this proportion was the lowest in the South (13%) (Table 1). Urine completion rate was lowest in urban areas, among elderly males with lower education level, median monthly income, underweight, or diabetes.

Among those with complete urine collection, the mean age was 44.3 years (range 18-85 years) and 53% were female. Majority (66%) had above secondary level of education. In all, 30% had hypertension, 44% were overweight or obese, and 7.2% had a history of being diagnosed with diabetes previously. Characteristics of study population across regions showed some variations in socio-demographic variables (Table 2). Also, the North-east Region had a significantly lower proportion of hypertensive population and Bangkok had the lowest proportion of overweight and obese population.

3.2 | Weighted mean 24-hour urinary sodium excretion by regions

Overall weighted mean 24-hour urine sodium excretion in Thailand was 3305 mg (Table 3). Sodium excretion was highest in the South

	North		North-east		South	
Median (IQR)	Mean (SD)	Median (IQR)	Mean (SD)	Median (IQR)	Mean (SD)	Median (IQR)
1245 (935-1920)	1846.4 (874.1)	1645 (1135-2340)	1569.2 (766.2)	1430 (985-1850)	2665.7 (1034.5)	1530 (1030-2330)
1276.2 (1035.5-1552.2)	1189.7 (330.6)	1120 (946.2-1370.5)	1256.5 (402)	1168.4 (959.5-1449.4)	1381.1 (433.6)	1210.4 (993.6-1493.5)
3127.8 (2373.5-3994)	3238.8 (1727.6)	2936 (2074.8-4128.5)	3014.3 (1461.9)	2720.9 (2018.9-3873.2)	3734.4 (1524.3)	2992.8 (2252.4-4108)
1070 (759.4-1467.3)	1157 (433.3)	1077.3 (866.2-1377.1)	1259.9 (478.8)	1193.6 (926.5-1490.2)	1382.3 (471.9)	1143.1 (869.2-1488.4)
1.2 (0.9-1.6)	1.4 (0.7)	1.3 (0.9-1.8)	1.2 (0.6)	1.1 (0.8-1.5)	1.4 (0.6)	1. 2 (0.9-1.6)
5.1 (3.7-6.9)	5.1 (2.8)	4.5 (3.2-6.4)	4.3 (2.1)	4 (2.8-5.4)	4.8 (2.1)	4.5 (3.3-6.1)
3440.5 (2610.8-4393.3)	3562.7 (1900.4)	3229.5 (2282.3-4541.4)	3315.8 (1608.1)	2993 (2220.8-4260.5)	4107.8 (1676.8)	3292 (2477.6-4518.8)
8.6 (6.5-10.9)	8.9 (4.7)	8.0 (5.7-11.4)	8.3 (4.0)	7.5 (5.6-10.6)	10.3 (4.2)	9.6 (7.2-12.4)

region (3734 mg), followed by Central, North, and Bangkok, and lowest in the North-east Region ($p < .001$). With 10% inflation to adjust for losses of sodium in sweat and feces, the corresponding estimated daily dietary salt intake was highest in the South Region (10.3 g), followed by Central (9.4 g), North (8.9 g), Bangkok (8.7 g), and lowest in North-east Region (8.3 g) ($p < .001$), respectively. The mean 24-hour urine potassium excretion was 1221 mg with little variation across Region (Table 3). Potassium excretion was similar in men and women and across age groups (data not shown). The overall mean urine Na/K ratio was 5, and it was highest in the Central Region (5.5 ± 2.6).

3.3 | Weighted mean sodium intake by participants' characteristics

Apart from regional variations, there were notable differences in sodium intake by socio-demographic and clinical characteristics of the population (Figure 1). Mean sodium intake was higher among participants with secondary level of education 3784 mg (95% CI 3565-3903) than those with primary education 3347 mg (95% CI: 3192-3503). There was a dose-response relationship between sodium intake and BMI. Participants with hypertension had higher sodium intake 3788 mg (95% CI: 3615-3961) than those without hypertension 3561 mg (95% CI: 3449-3673).

3.4 | Factors associated with high sodium consumption

When adjusted for available confounding factors as shown in Table 4, participants from the Southern Region (AOR: 3.53, 95% CI 1.91-6.53; $p = .000$) and Central Region (AOR: 2.32, 95% CI 1.31-4.13; $p = .004$) were more likely to consume excess sodium > 2000 mg per day compared with Bangkok. Higher sodium consumption was independently associated with younger age groups [18-29 years (AOR 2.81, 95% CI: 1.53-5.17; $p = .001$); 30-44 years (AOR 2.09, 95% CI: 1.21-3.61; $p = .008$)]; higher education (AOR 1.79; 95% CI: 1.19-2.67; $p = .005$); BMI ≥ 25 (AOR 1.55; 95% CI 1.09-2.21; $p = .016$); and hypertension (AOR 1.58; 95% CI 1.02-2.44; $p = .038$). No significant association was noted between sodium consumption and sex, residential area, monthly income, or history of diabetes ($p > .05$). We also found that results from multivariate linear regression using mean sodium consumption were consistent with those from multivariate logistic regression (data not shown).

4 | DISCUSSION

The first nationally representative population-based survey in Thailand using 24-hour urine collection methodology indicated that the average urinary sodium excretion was 3305 mg/day. Applying the evidence that about 90% of the sodium consumed is excreted in urine,[19] the mean dietary sodium intake in Thai population in 2019-2020 was estimated to be 3636 mg/day (equivalent to salt intake of 9.1 g/day).

Dietary sodium intake in the Thai population is nearly twice the amount recommended by WHO. High sodium consumption in the population is attributed to the generous use of condiments and seasonings while cooking and at the table. Earlier studies have indicated that approximately 90% of dietary sodium comes from condiments such as fish sauce, soy sauce, salt, and seasoning cube.[10] In addition, monosodium glutamate or MSG is commonly used in most Thai recipes for its *Umami* flavor.[20,21] Moreover, the use of packaged and ready to eat food such as instant noodles, frozen foods, all high in sodium is also population and on the rise.

The estimated mean dietary sodium intake in Thailand is comparable with the global average (3720 mg/day)[22] and is within the range reported by western countries: United States (3608 mg/day),[23] Australia (3560 mg/day), and Canada (3325 mg/d).[23-25]

Interestingly, estimated sodium intake in Thailand was lower than in its Asian neighbors: India (3720 mg/d in Delhi and 4098 mg/day in Andhra Pradesh); South Korea (3960 mg/day); China (4349 mg/day); Nepal (5280 mg/day); and Bangladesh (6800 mg/day).[26-30] Whether the comparatively lower estimates found in this study reflect a recent declining trend in Thailand cannot be stated with certainty due to the lack of previous studies using 24-hour urine collections. While the results of this survey can be generalized to Thailand owing to the large and representative sample of the study, the findings may not be applicable directly to other Asian countries due to significant differences in dietary patterns among countries. Future surveys are necessary on a nationally representative sample using similar methodology to infer conclusively about trends in sodium consumption in the Thai population.

Sodium intake was above 3000 mg in all areas, although significant variations were noted across Regions. Sodium intake was highest in the South Region followed by Central Region. According to available information, the top three condiments contributing to dietary sodium in the South Region are salt, fish sauce, and shrimp paste.[31] Anecdotally, several cultural practices related to cooking, processing, and consumption patterns may also play a role in higher sodium intake in the South Region. First, seafood is the staple diet in the South due to its proximity to the coast; majority of popular seafood dishes including shellfish and octopus have notably high sodium content. Second, preservation of seafood with salt is a routine practice during food processing and cooking. Third, in addition to regular condiments, the southern diet includes a special spicy shrimp paste and fish sauce (*Budu*) which contains high amount of sodium (4751 mg sodium per 100 gm). The high sodium intake in the Central Region could be due to the large population of factory workers who usually consume most meals outside home. Surprisingly, sodium consumption was the lowest in the north-east Region even though available studies indicate that consumption of fermented fish high in sodium is quite common in this Region. As data in the North-east Region were collected during COVID-19, it is possible that dietary habits may have temporarily changed during a time of a crisis. Quantitative and qualitative study are needed to better understand dietary patterns responsible for differences in sodium consumption in the different Regions of Thailand and devise customized communication strategies to support communities for reducing sodium consumption.

Our study shows that higher sodium intake (above 2000 mg/day) was independently associated with hypertension, overweight and obesity, higher education, and younger age group. An earlier national survey also found that sodium intake was higher sodium among younger population [11] which may explained partly due to higher caloric intake and consumption of fast food among young people.[32,33] There is growing empirical evidence in support of a positive relationship between sodium intake and BMI[34-36] which may result from increased consumption of sugar-sweetened beverages[32,37] and calorie dense fast food.[38] High salt intake is also reported to be associated with greater deposition of subcutaneous abdominal adipose tissue and body fat.[39,40] The evidence of a positive association between BMI and salt intake in our study and other studies underscores the importance of addressing behavioral and metabolic risk factors through comprehensive multipronged strategies. Such comprehensive efforts comprising engagement with food industry for reformulation, introduction of front-of-pack warning labels, increasing the availability of low sodium recipes in schools and workplace settings, and restricting marketing of unhealthy food and beverages in conjunction with mass public awareness campaigns have led to an extensive decrease in energy, total sugar, and sodium content for the most frequently consumed packaged food products in Chile[41] and a 24% reduction in dietary sodium consumption in South Korea.[42] Similar approaches are needed in Thailand.

Consistent with other studies, our study demonstrated a significant positive relationship between high sodium intake and hypertension.[43,44] Increased sodium sensitivity is cited as a possible reason for higher consumption among hypertensive patients.[45] Thailand has a high prevalence of raised blood pressure with an estimated 13.2 million estimated to have hypertension.[7] Currently, 7 million patients are registered for treatment for hypertension and have regular contact with a public health facility once in three months.[46] These encounters can be used as opportunities to offer nutrition counseling for sodium reduction both to patients and to their relatives. Intervention research should be undertaken to assess the effectiveness and impact of different nutrition counseling strategies on sodium consumption and blood pressure control among patients with hypertension.

In addition to high sodium intake, an imbalanced diet with low potassium consumption is also an important determinant of raised blood pressure.[43,47] The WHO recommends a minimum daily intake of 3,510 mg of potassium and a 1:1 sodium to potassium (Na/K) ratio.[48] The mean urinary potassium excretion in this study was 1,221 mg/d (30% of the recommendation), while the mean Na/K molar ratio was five times the WHO recommended level. Although urinary potassium excretion is an uncertain indicator of dietary potassium intake,[49] given the high prevalence of hypertension in Thailand[31] strategies should be considered to reduce sodium and increase potassium intake. Apart from public awareness campaigns and fiscal policies to promote fruits and vegetables, salt substitutes containing potassium chloride can be a potentially important strategy to reduce sodium and increase potassium intake, thereby lowering blood pressure.[50] Additionally, there is a need to study the feasibility, acceptability, safety, and cost-effectiveness of introducing potassium enriched sodium substitutes in Thai population.

Our study has several strengths. This large population-based survey in adult men and women across several age groups draws sample from both urban and rural areas in 13 out of 76 provinces of Thailand. Almost all participants (except 12) agreed to participate in the study and provided a 24-urine specimen. High participation could be achieved in part due to the involvement of health volunteers who are highly trusted by communities. Additionally, a nominal financial incentive of 500 THB (15 USD) may have helped in recruitment of participants. Despite using stringent criteria for exclusion, the net response rate was as high as 67% which is comparable or higher than other studies.[23,26] Although implementation of a large

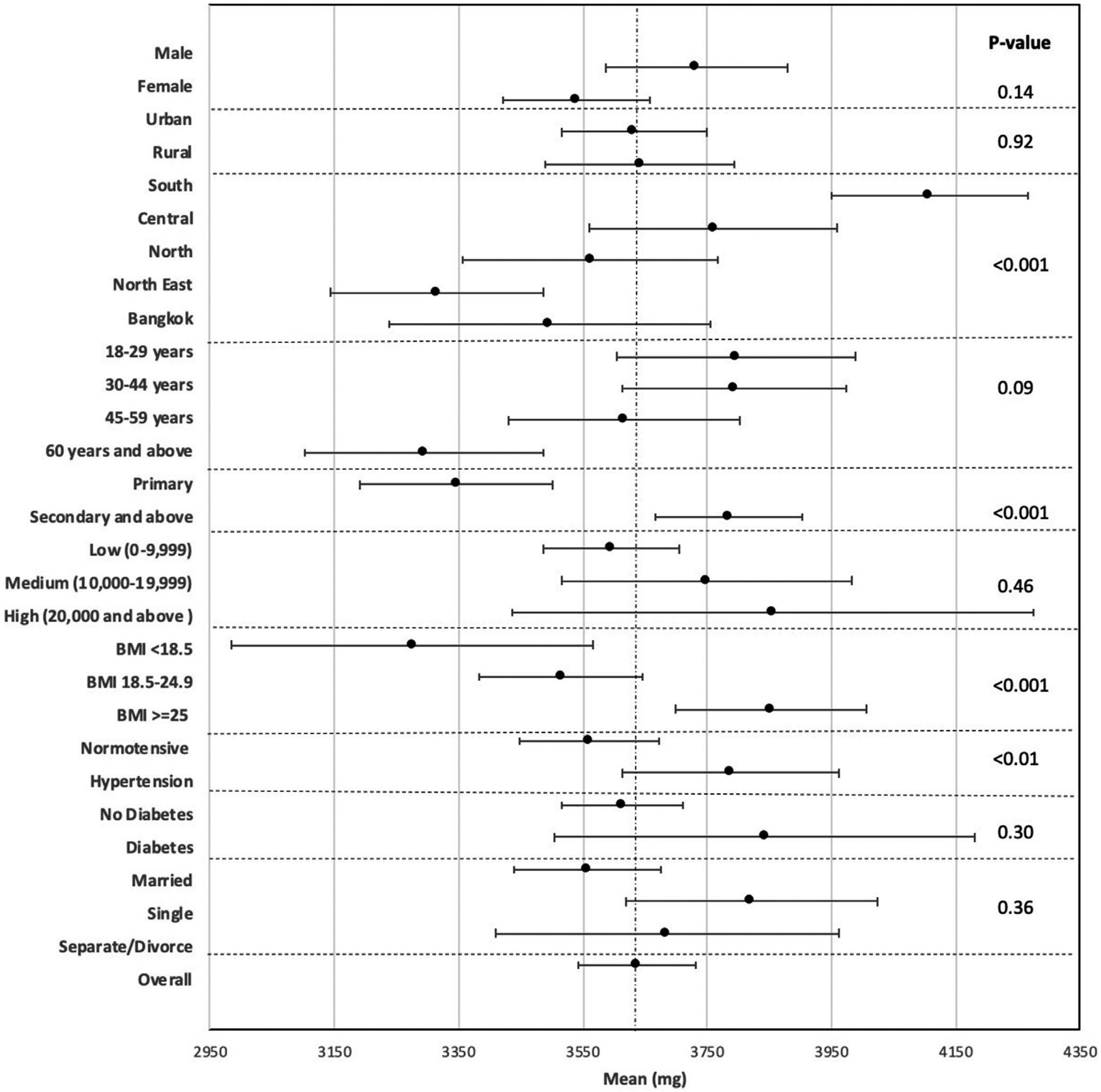

FIGURE 1 Forest plot of weighted mean sodium consumption, by population characteristics (Data expressed as mean and 95% CI)

nationwide, field-based survey using 24-hour urine collections was resource intensive and logistically challenging, it contributed to build institutional capacity in the capital and four regions of the country. It also helped to establish a rigorous survey protocol which can be replicated for future monitoring.

The study also has some limitations. First, urine completion rates varied by population characteristics and were significantly lower in the Central Region. We were unable to adjust for these differences which may have skewed our findings toward producing an overall estimate influenced by populations that are over-represented in the study. Second, despite our best efforts to ensure complete urine collection, it is possible that some participants may not have provided complete urine collections. We overcame this limitation to a great extent by using stringent and objective inclusion criteria based on urine volume and creatinine excretion. Yet it is possible that some specimens may have been incomplete. Further analysis excluding those potentially incomplete specimens did not substantially change the estimates. Based on these analyses, we believe that the overall impact of the incomplete urine collection in our study is that it resulted in underestimating sodium and potassium excretion.

Third, although we weighted our data to account for sampling probability based on age structure of each area, it was not possible to adjust for all potential confounders. Finally, although we aimed to collect urine specimens on all days of the week, most participants

TABLE 4 Factors associated with high sodium consumption (>2000 mg/day)

Characteristics	Adjusted Odds Ratio	95% CI	*p*-value
Sex			
Female	1.00		
Male	1.11	0.80-1.54	.545
Region			
Bangkok	1.00		
Central	**2.32**	**1.31-4.13**	**.004**
North	1.14	0.64-2.03	.655
Northeast	1.27	0.70-2.30	.438
South	**3.53**	**1.91-6.53**	**.000**
Area			
Rural	1.00		
Urban	1.28	0.89-1.84	.188
Age group			
60 years and above	1.00		
45-59 years	1.22	0.78-1.90	.387
30-44 years	**2.09**	**1.21-3.61**	**.008**
18-29 years	**2.81**	**1.53-5.17**	**.001**
Education level			
Primary	1.00		
Secondary and above	**1.79**	**1.19-2.67**	**.005**
Income (Thai baht per month)			
Low (0-9999)	1.00		
Medium (10-19 999	0.75	0.47-1.21	.241
High (20 000 and above	1.66	0.76-3.64	.203
Body mass index (Kg/m^2)			
18.5-24.9	1.00		
<18.5	0.72	0.36-1.42	.338
25 and above	**1.55**	**1.09-2.21**	**.016**
Hypertension*			
No	1		
Yes	**1.58**	**1.02-2.44**	**.038**
History of diabetes			
No	1		
Yes	1.20	0.63-2.27	.583

*Hypertension was defined as anyone with systolic blood pressure ≥ 140 and or diastolic blood pressure ≥ 90 mm Hg or taking medication for hypertension. Bold significance are P-value <0.05.

provided specimens on weekends. Eating patterns on weekends can be variable—working population may prefer to eat at home whereas others may prefer to go out on weekends. These eating patterns may have skewed sodium consumption estimates in our study in one or the other direction. It is important to take this into account while planning and implementing the next survey, so that urine collection protocol in the next round is as consistent as possible to the protocol implemented in this round.

5 | CONCLUSIONS

The first nationally representative population-based survey using 24-hour urinary analyses indicates that dietary sodium consumption among Thai adults is 3635 mg/day, about twice the amount recommended by WHO. These findings call for accelerating the implementation of multipronged interventions which are included in Thailand's national sodium reduction strategy SALTS, namely (a) improving the quality of nutrition programmes in **settings** such as schools, workplaces and communities (S); (b) Public **awareness** (A); (c) **legislation** for to regulate sodium level in packaged food, effective front-of pack food labeling, and restriction on marketing of unhealthy foods (L); (d) use of innovation and **technology** to develop suitable sodium substitutes (T); and (e) regular **surveillance** (S). In contribution to the surveillance component of the SALTS strategy, our study provides a robust estimate for tracking progress toward population national sodium reduction goals. Better understanding is needed of reasons for higher sodium intake in Southern and Central Regions and among younger and more educated populations. Furthermore, combined and comprehensive action is needed to address clustering of multiple risk factors, viz, high sodium consumption, BMI ≥ 25kg/m^{2,} and hypertension. Surveys using consistent methodology conducted every 3-5 years should help to monitor progress and fulfill Thailand's global commitments to prevent avoidable morbidity and premature mortality from cardiovascular disease.

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CONFLICT OF INTEREST

None.

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