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Urinary sodium excretion is associated with increased body mass index: A cross-sectional analytical study among adults in Kuala Lumpur, Malaysia

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ABSTRACT

The relationship between urinary sodium excretion and obesity is a critical area of research to understand the interactions among dietary sodium, weight gain, and the initiation of public health interventions to address obesity. This study aims to determine the association between urinary sodium excretion and body mass index (BMI). A cross-sectional study was conducted among 216 adults aged 18-65 years old who were recruited using convenience sampling in Kuala Lumpur, Malaysia. The overall mean urinary sodium was 274.00±127.57 mmol/L. Those with high levels of urinary sodium (T3) had significantly higher mean BMI (T3: 26.71±6.31 mmol/L; F=4.01, p=0.019). Age (F=6.24, p<0.001), occupational status (F=4.06, p=0.001), ethnicity (F=8.53, p<0.001), marital status (t=-3.61, p<0.001), and monthly household income (F=4.91, p<0.001). Hypertension (F=4.15, p<0.001) was also significantly associated with increased BMI. Multivariate linear regression model identified urinary sodium excretion concentration (Adjusted β=0.19, 95% CI=0.01, 0.03, p=0.003), ethnicity (Adjusted β=0.18, 95% CI=0.06, 1.10, p=0.030), occupational status (Adjusted β=-0.23, 95% CI=-0.97, -0.06, p=0.026), and having heart disease/stroke (Adjusted β=0.17, 95% CI=1.96, 13.43, p=0.009) were significantly associated with increased BMI. The findings highlight the need for a concerted effort and intervention towards a low-sodium or salt diet to maintain a normal BMI.

Keywords: *Adults; body mass index; obesity; public health and sodium*

INTRODUCTION

Sodium is one of the essential minerals required by the human body to function and helps to maintain the fluid and blood volume in the human body. It is found in the blood and lymph fluid (Ahmad et al., 2021), plays a major role in conducting nerve impulses between the brain and body, and aids in the contraction and relaxation of the muscles (WHO, 2023). The gold standard to measure sodium intake is through 24-hour urine collection as the majority of the sodium consumed (90–95%) is excreted through the urine (Jarrar et al., 2020); however, the burdensome in large-scale studies add both economic loads (Tinker et al., 2021) and psychological responsibilities among the subjects (Gong et al., 2022). Hence, the collection of one spot or casual urine samples is suggested as an alternative approach (Ji et al., 2021) which is more convenient and preferred in large population studies (Yeung et al., 2021).

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Adults are encouraged to practice moderate consumption of dietary salt intake less than 5 grams (g) or less than 2000 milligrams (mg) of sodium daily (WHO, 2023). Precisely, for adults aged between 19 years old and above, a dietary sodium intake of 1500 mg per day is recommended (Recommended Nutrient Intake (RNI) for Malaysia, 2017). However, according to the latest population-based salt intake survey conducted in Malaysia, about 79% of Malaysian adults have a high dietary sodium intake in their daily diet (Pardi et al., 2022). According to the Malaysian Community Salt Survey (MyCoSS) in 2021, the mean 24-hour sodium intake among Malaysian adults was 3167 mg per day, which corresponds to 7.9 grams of salt, much higher than WHO's recommended dietary sodium intake of 2000 mg per day (WHO, 2023), which corresponds to 5 grams of salt intake (Ambak et al., 2021). High salt intake was linked with high blood pressure and other health conditions, including obesity (Lee et al., 2023). "Reverse causality" is the common fourth explanation, according to which subjects with comorbid conditions such as hypertension and heart failure either have a low sodium consumption as an advisable therapy or suffer from malnourishment due to inadequate dietary (and sodium) intake. This explanation becomes less compelling when large cohort studies are conducted with appropriate statistical analysis to account for comorbidities as confounding factors while assessing the association between sodium and disease risk (Giri et al., 2023). While the scientific community broadly recognizes the harmful effects of dietary salt, and thus sodium intake in the human body (Jaques & Ponte, 2023), the specific effect of sodium excretion (not solely from the diet) on health and disease risk is less well understood. Although high consumption of calorie-dense food is the leading cause of obesity, dietary sodium intake was associated with distinctive obesity outcomes such as BMI, body weight, and waist circumference. This potential mechanism can be first explained in terms of the intake of dietary sodium, which involves the increased pro-inflammatory adipocytokine secretion and adipogenesis/lipogenesis, and further decreases the lipolysis in adipocytes in a dose-dependent manner, which leads towards inflammatory adipogenesis, hence results in obesity. Being overweight and obese are significant risk factors for many chronic diseases, including cardiovascular diseases such as heart disease and stroke, which are the world's leading causes of death (Rajendran et al., 2023; Safaei et al., 2021).

There are 50.1% of Malaysian adults who are overweight or obese, with 30.4% being overweight, 19.7% obese, and 52.6% having abdominal obesity (IPH, 2020). Hence, this signifies that half of the Malaysian adults are either overweight or obese and indicates the need for efficient interventions to promote population-wide improved dietary patterns and healthier lifestyle practices. In Malaysia, obesity rates accelerated in the low-income (B40) group (Andoy-Galvan et al., 2020). BMI is the most common obesity measurement used to predict the risk of developing distinct chronic conditions such as diabetes, hypertension, depression, and cancer (Khatib et al., 2021; Oniszczenko & Stanisławiak, 2019). Implementing effective health policies will significantly reduce the burden of chronic diseases, improve life quality, lower healthcare costs, and address the prevalence of overweight or obesity.

To date, in Malaysia, the Malaysian Community Salt Survey (MyCoSS), has identified that being obese increases the consumption of sodium assessed by urinary sodium (Sallehuddin et al., 2021). This current study is the first study aimed at determining the independent association of urinary sodium excretion with BMI controlled for potential comorbidities, socio-demographic backgrounds, and medical characteristics.

METHODOLOGY

Subjects and location

This was a cross-sectional study involving 216 adults aged 18-65 years who visited a private medical clinic in Kuala Lumpur, Malaysia, from March to April 2022, using convenience sampling. The sample size was calculated using Daniel's formula, with a precision of 0.05 at an 80% statistical power, and assuming a drop-out percentage of 20% as the response rate might not correspond to the expected outcome (Daniel, 2011). Subjects who were pregnant, with severe diseases, on any diuretic therapy treatment within four (4) weeks, fasting, having menstruation, or having any difficulty collecting urine were excluded, and subjects who were adults and able to write and converse in Bahasa Melayu or English were included in this study.

Ethics approval

Ethics approval was obtained from UCSI University Institutional Ethics Committees (IEC-2021-FAS-030) on 11th June 2021 followed by permission from the medical clinic, which was obtained verbally while ensuring compliance with the ethical and institutional requirements. An information sheet was provided, and a written consent form was obtained from the subjects before their commitment to this study. All the required guidelines and regulations according to IEC, MREC, and the medical clinic were adhered to during this study (Fletcher, 2015).

Interviewee-administered questionnaire

A pre-tested and validated self-administered questionnaire was distributed among the subjects after obtaining their written consent. The questionnaire was used to assess (i) the sociodemographic background namely gender, age, ethnicity, occupation status, marital status, academic qualifications, and monthly household income, (ii) medical background such as presence of hypertension, heart disease/stroke, diabetes, high cholesterol, family history of chronic disease, intake of painkillers, herbs/traditional medicine and special diet and, (iii) smoking habit and (iv) blood pressure was measured.

Anthropometry measurement

The anthropometric measurement involves the measurements of the subjects' standing height, body weight, body circumferences for adiposity (waist and hips), body fat percentage, blood pressure, and the body mass index is calculated from the body weight and standing height. The Omron Karada scan body composition monitor weighing scale was used to measure the body weight (Ulaganathan & Sann, 2021), followed by the SECA 213 stadiometer to measure the height with an accuracy of 0.1 cm, respectively (Kusters & Driessen, 2011). Both height and weight measurements were taken twice, and the average was recorded as the final reading. The body fat percentage was measured using the Omron body fat monitor, and the Omron blood pressure monitor was used to measure the blood pressure (El Assaad et al., 2002). The body circumferences were measured using the Seca measuring tape.

Urine full examination and microscopic examination test

One spot sample of urine was collected from each subject using sterilized urine containers, 50 ml, to ensure that there was no contamination, hence the results will not be affected. The subjects were instructed to collect midstream portion of their urine and special preparation; for instance, fasting was not required. Collected urine samples were immediately transferred into cooler boxes at 4 °C to maintain stability and prevent overgrowth of potential organisms during transportation to the laboratory. Urine sodium excretion was measured using the urine full examination and microscopic examination (FEME). If any of the urine samples leaked out from the container before the biochemical analysis, or the urine volumes were insufficient for urine FEME, that urine sample would be excluded from this study. The normal urinary sodium value of an adult is expected to be between 40 to 220 millimoles per Liter (mmol/L) per day (Lee et al., 2022), conversion from milliequivalents to milligrams was made by multiplying by a factor of 23.

Data analysis

The IBM Statistical Package Social Sciences (SPSS) version 21.0 analyzed all the statistical data. Descriptive statistics were computed to determine the frequency, percentage, mean, and standard deviation of the dependent and independent variables. The independent t-test and One-Way ANOVA test determined the association between the subjects' characteristics and increased BMI. The univariate and multivariate regression analysis was conducted to determine the association of the urinary sodium excretion and other study variables with BMI. Multiple linear regression was performed to determine the independent effect of urinary sodium excretion, with BMI controlled for potential confounding variables (Rahayu et al., 2024).

RESULTS

Characteristics of subjects

Table 1 below shows that the mean urinary sodium excretion was 274.0 ± 127.6 mmol/L. The mean age of the 216 subjects is 34.5 ± 12.4 years old. The majority of the subjects are 30 years old and below (44.0%), females (55.6%), Malay (43.5%), married (48.1%), had tertiary education (64.4%), had full-time employment (55.6%), and had a monthly household income ≥ RM 4850 (34.3%). The mean systolic blood pressure score was 121.4 ± 17.7 mmHg, and the diastolic blood pressure was 81.0 ± 11.5 mmHg. The prevalence of hypertension was (17.6%), heart disease/stroke (1.4%), diabetes (4.6%), high cholesterol (24.5%), and a family history of chronic disease (58.3%). The majority of subjects are taking painkillers less than once a month (75.5%), while 10.6% consume herbs or traditional medicine, and 10.2% are on a special diet such as gluten-free, ketogenic, vegetarian, Dietary Approaches to Stop Hypertension (DASH), or vegan diets. In comparison, the proportion of respondents who had ever smoked cigarettes was 31.0%.

The mean body mass index distribution across the subjects' characteristics

Table 1 represents mean BMI distribution across the subjects' characteristics. The mean BMI significantly increased across tertiles, namely T1 (low), T2 (moderate) and T3 (high). Those 41-50 years old have the significantly highest mean BMI, while those 31 – 40 years old have the lowest mean BMI. Indians have the highest mean BMI compared to other ethnicities. Those with part-time employment have the highest mean BMI, while students have the lowest mean BMI. The monthly household income, RM 3171 to RM 3970, has the significantly highest mean BMI, while those with no income have the lowest mean BMI. Compared to single subjects, those who were married had higher mean BMI. Subjects with hypertension, heart disease or stroke, and those with a special diet have significantly higher mean BMI than normal subjects.

Table 1
Distribution of mean body mass index across the study characteristics

Variables	All n (%)	BMI (kg/m^2) mean ± SD	One-Way ANOVA	t-test	p-value
Urinary sodium (mmol/L) excretion (mean ± SD)	274.0 ± 127.6				
T1: Low	72(33.3)	25.5±4.7	4.01		0.019*
T2: Moderate	73(33.8)	24.2±4.9			
T3: High	71(32.9)	26.7±6.3			
Gender					
Male	96(44.4)	25.1±4.4		-0.87	0.386
Female	120(55.6)	25.7±6.1			
Age (years) (mean ± SD)	34.46 ± 12.40				
30 and below	95(44)	23.8± 4.5	6.24		< 0.001*
31-40	53(24.5)	26.0±5.2			
41-50	34(15.7)	27.6±6.8			
51-60	34(15.7)	25.5±5.4			
Ethnicity					
Malay	94(43.5)	26.8±5.8	8.53		< 0.001*
Chinese	55(25.5)	23.4±4.0			
Indian	8(3.7)	30.8±7.4			
Others	59(27.3)	24.5±4.5			
Academic qualifications					
Primary and Secondary Education	77(35.65)	25.4±5.4		-0.04	0.965
Tertiary Education	139(64.35)	25.5±5.4			
Occupation status					
Full-time employment	120(55.6)	26.7±5.8	4.06		0.001*
Part-time employment	5(2.3)	28.3±6.6			
Self-employment	8(3.7)	26.4±5.7			
Housewife	4(1.9)	27.8±3.7			
Unemployed	2(0.9)	23.4±0.9			
Student	76(35.2)	23.2±4.0			
Marital Status					
Single	104(48.1)	24.2±4.9		-3.61	<0.001*
Married	104(48.1)	26.8±5.6			
Monthly household income (RM)					
No income	52(24.1)	23.2±3.1	4.91		< 0.001*
≤ RM 2500	32(14.8)	24.1±5.5			
RM 2501-RM 3170	28(13.0)	25.4±4.7			
RM 3171-RM 3970	15(6.9)	27.8±6.2			
RM 3971- RM 4850	15(6.9)	23.3±5.2			
≥ RM 4850	74(34.3)	27.3±5.7			
Blood Pressure (mmHg) (mean ± SD)					
Systolic	121.37 ± 17.67				
Diastolic	81.08 ± 11.53				
Hypertension					
Yes	38(17.6)	26.8±5.3		4.12	< 0.001*
No	178(82.4)	23.8±5.1			
Heart Disease/ Stroke					
Yes	3(1.4)	32.5±6.1		2.28	0.024*
No	213(98.6)	25.4±5.4			
Diabetes					
Yes	10(4.6)	28.1±9.1		1.28	0.231
No	206(95.4)	25.3±5.2			

Note: Data are expressed as percentage (%) or mean ± standard deviation (SD). BMI= Body Mass Index; RM: Malaysian Ringgits; mmHg: millimetres of mercury; Independent t-tst was used for comparisons between two groups; One-way analysis of variance (ANOVA) for comparisons among more than two groups; p < 0.05 indicates statistically significant association with BMI.

Table 1 (continued)
Distribution of mean body mass index across the study characteristics

Variables	All n (%)	BMI (kg/m^2) mean ± SD	One-Way ANOVA	t-test	p-value
High Cholesterol					
Yes	53(24.5)	26.7±5.7		1.91	0.058
No	163(75.5)	25.1±5.3			
Family History of Chronic Disease					
Yes	126(58.3)	25.1±5.6		1.65	0.100
No	90(41.7)	24.7±5.1			
Painkillers					
At least once a day	2(0.9)	30.4±15.7	1.541		0.205
At least once a week	3(1.4)	21.1±3.6			
At least once a month	48(22.2)	26.2±4.8			
Less than once a month	163(75.5)	25.3±5.5			
Herbs/Traditional Medicine					
Yes	23(10.6)	26.0±6.1		0.55	0.585
No	193(89.4)	25.4±5.3			
Special Diet					
Yes	22(10.2)	27.9±6.0		2.28	0.024*
No	194(89.8)	25.2±5.3			
Smoked					
Yes	67(31.0)	25.9±4.9		0.71	0.478
No	69(69.0)	25.3±5.6			

Note: Data are expressed as percentage (%) or mean ± standard deviation (SD). BMI= Body Mass Index; RM: Malaysian Ringgits; mmHg: millimetres of mercury; Independent t-tst was used for comparisons between two groups; One-way analysis of variance (ANOVA) for comparisons among more than two groups; p < 0.05 indicates statistically significant association with BMI.

The mean body mass index distribution across the subjects' characteristics

Table 1 below represents the mean BMI distribution across the subjects' characteristics. The mean BMI significantly increased across tertiles, namely T1(low), T2 (moderate) and T3 (high). Those 41-50 years old have the significantly highest mean BMI, while those 31 – 40 years old have the lowest mean BMI. Indians have the highest mean BMI compared to other ethnicities. Those with part-time employment have the highest mean BMI, while students have the lowest mean BMI. The monthly household income, RM 3171-RM 3970, has the significantly highest mean BMI, while those with no income have the lowest mean BMI. Compared to single subjects, those who were married had a higher mean BMI. Subjects with hypertension, heart disease/ stroke, and those with a special diet have significantly higher mean BMI than normal subjects.

Association between the urinary sodium excretion, subjects' characteristics, and body mass index

Table 2 below represents that the urinary sodium excretion was significantly associated with increased BMI (Crude-β=0.15, 95% CI=0.002, 0.02, p=0.024). There was a positive significant association between age and BMI (Crude- β= 0.27, 95% CI= 0.06, 0.17, p< 0.001). Occupational status was negatively associated with increased BMI (Crude- β=-0.30, 95% CI=-0.99, -0.40, p<0.001). Higher monthly household income was positively associated with increased BMI (Crude-β=0.26, 95% CI=0.34, 1.03, p< 0.001). Systolic blood pressure (Crude- β=0.24, 95% CI=0.03, 0.11, p< 0.001) and diastolic blood pressure (Crude- β=0.32, 95% CI=0.09, 0.21, p< 0.001) were positively associated with increased BMI. There was a positive association between hypertension (Crude- β=0.27, 95% CI=1.54, 4.37, p< 0.001), heart disease/stroke (Crude-β=0.15, 95% CI=0.96, 13.25, p=0.024), diabetes (Crude- β=0.14, 95% CI=0.27, 7.13, p=0.035), and increased BMI. Those on special diet (Crude- β=0.15, 95% CI=0.37, 5.13, p=0.024) were positively significantly associated with increased BMI. Out of 17 variables in univariate analysis, 11 significant variables from the univariate analysis were selected to be included in the multivariate linear regression model to determine the independent association between urinary sodium excretion and BMI and related predictors.

Table 3 below represents the multivariate linear regression analysis, an increased in one unit of mmol/L of urinary sodium excretion, increases the BMI by 19% (Adjusted β=0.19, 95% CI=0.01, 0.03, p=0.003). Ethnicity was positively associated with BMI (Adjusted β=0.18, 95% CI=0.06, 1.10, p=0.030). Occupational status was inversely associated with BMI (Adjusted β=-0.23, 95% CI=-0.97, -0.06, p=0.026). There was a positive association between having cardiovascular disease (CVD) or stroke and increased BMI (Adjusted β=0.17, 95% CI=1.96, 13.43, p= 0.009). Age, monthly household income, systolic blood pressure, diastolic blood pressure, hypertension, diabetes, and special diet were not associated with increased BMI.

Table 2

Univariate regression analysis to determine the association between urinary sodium, study subjects' characteristics, and body mass index

Variables	Crude- β	95% CI	p-value
Sodium (mmol/L)	0.15	0.002, 0.02	0.024*
Age (years)	0.27	0.06, 0.17	< 0.001*
Ethnicity	-0.13	-0.87, 0.03	0.051**
Gender	-0.01	-0.23, 0.05	0.456
Highest academic qualifications	0.003	-1.49, -1.55	0.965
Occupation status	-0.30	-0.99, -0.40	< 0.001*
Monthly Household Income (RM)	0.26	0.34, 1.03	< 0.001*
Systolic Blood Pressure (mmHg)	0.24	0.03, 0.11	< 0.001*
Diastolic Blood Pressure (mmHg)	0.32	0.09, 0.21	< 0.001*
Hypertension	0.27	1.54, 4.37	< 0.001*
Heart Disease/ Stroke	0.15	0.96, 13.25	0.024*
Diabetes	0.14	0.27, 7.13	0.035*
High Cholesterol	0.13	-0.05, 3.30	0.058**
Family History of Chronic Diseases	0.11	-0.24, 2.70	0.100
Painkillers	-0.06	-1.96, 0.77	0.391
Herbs/ Traditional Medicine	0.04	-1.71, 3.01	0.585
Special Diet	0.15	0.37, 5.13	0.024*
Smoked	0.05	-1.00, 2.14	0.478

Note: Data are presented as Crude regression coefficients (Crude- β) with 95% confidence intervals (CI); BMI: Body Mass Index; RM: Malaysian Ringgits; mmHg: millimetres of mercury; p < 0.05 indicates statistically significant association.

Table 3

Multivariate regression analysis to determine the association between urinary sodium excretion and body mass index controlled for the subjects' characteristics

Variables	B	S.E.	Adjusted β	95% CI	p-value
Sodium (mmol/L)	0.017	0.006	0.19	0.01, 0.03	0.003*
Age (years)	0.044	0.041	0.10	-0.04, 0.13	0.284
Ethnicity	0.578	0.265	0.18	0.06, 1.10	0.030*
Occupational Status	-0.518	0.231	-0.23	-0.97, -0.06	0.026*
Monthly Household income (RM)	0.104	0.251	0.04	-0.39, -0.60	0.678
Systolic (mmHg)	-0.140	0.915	-0.01	-1.95, 1.67	0.879
Diastolic (mmHg)	0.339	1.649	0.03	-2.91, 3.59	0.837
Hypertension	2.076	1.674	0.19	-1.23, 5.38	0.217
Heart Disease/ Stroke	7.695	2.907	0.17	1.96, 13.43	0.009*
Diabetes	1.319	1.787	0.05	-2.21, 4.84	0.461
Special Diet	1.707	1.208	0.10	-0.66, 4.09	0.159

Note: Data are expressed as regression coefficient (B); Standard error (S.E); adjusted regression coefficient (adjusted β) and 95% confidence interval (CI); BMI: Body Mass Index; RM: Malaysian Ringgits; mmHg:millimetres of mercury; p < 0.05 indicates statistically significant association.

DISCUSSION

This In this study, dietary sodium was significantly associated with increased BMI, indicating that Malaysian adults consumed an average of 3167 mg of sodium per day, which was more than the 2000 mg per day recommended by the WHO (WHO, 2023). The current study provides comprehensive insights into the independent direct association of urinary sodium excretion with BMI. A previous analytical cross-sectional study conducted among Malaysian adults in Kuala Lumpur highlighted a direct association between obesity and urinary sodium excretion. It was hypothesized that obese individuals tend to consume more dietary sodium, as assessed by urinary sodium excretion (IPH, 2020). Although both studies showed a direct association, the current study was able to provide evidence on how urinary sodium excretion predicts health outcomes in terms of BMI and adds new knowledge to the scientific body. Urinary sodium excretion is often used as a proxy for dietary sodium intake; therefore, high sodium intake was associated with increased appetite and consumption of high-calorie and energy-dense food, potentially contributing to weight gain over time, which leads to increased BMI (Lee et al., 2023). This finding corresponds with a study indicating that sodium consumption was linked to overweight/obesity and abdominal obesity, regardless of daily energy intake (Fang et al., 2021). Besides, in a study among the general US population, high sodium intake (>2300 mg/d) was significantly associated with the risk of obesity and central obesity compared to those with moderate sodium intake (1500-2300 mg/d) (Zhang et al., 2018). In addition, high sodium intake was also hypothesized to stimulate brain pathways involved in appetite regulation, leading to increased hunger and food intake (Porcari et al., 2022). Foods that are high in sodium, such as processed and fast foods, often also contain high levels of unhealthy fats, sugars, and calories; therefore, prolonged consumption of these foods can contribute to obesity over time (Clemente-Suárez et al., 2023; Ulaganathan et al., 2018). The current finding was in line with a cross-sectional study conducted among Korean adults, which showed that high urinary sodium excretion levels (≥ 3200 mg) doubled the odds of being overweight (OR = 2.17, 95% CI = 1.90, 2.49) and being abdominally obese (OR = 2.50, 95% CI = 2.13, 2.94) (Lee et al., 2018).

Furthermore, there was a significant positive association between the age group and increased BMI, the age group 41-50 years old accounted for the highest mean BMI score which was in line with a cross-sectional study conducted among Malaysian adults revealing that age group (OR = 1.40, 95% CI= 1.04, 1.88) was significantly associated with an augmented risk of obesity (Mohd-Sidik et al., 2021). As aging progresses, the primary daily energy expenditure decreases, and lifestyle practices alter, hence alleviating the adipose tissue accumulation and redistribution leading towards the accumulation of abdominal fat which is an explanation for the propensity to gain body fats and eventually increased BMI (Lim et al., 2024; Lorenzini et al., 2020) There was a significant association between occupational status and increased BMI, the results revealed that subjects with part-time employment have the highest mean BMI scores, and the students have the lowest mean BMI score. This underscores that extended periods of inactivity at work, sedentary lifestyle behaviors (Motuma et al., 2022), and prolonged sitting have been linked to a higher risk of obesity, specifically abdominal obesity (Sugiyama et al., 2020). Monthly income demonstrated a significant positive association with increased BMI, in line with a study conducted in China indicating that increased family income per year was significantly associated with increased BMI (β= 0.16, 95% CI=0.03, 0.29 (Xin & Ren, 2021). Several medical histories showed a significant positive association with an increase in BMI in this study. Hypertension (Yamada et al., 2023), heart disease/stroke (Cercato & Fonseca, 2019), diabetes (Al-Rashid et al., 2025), and cholesterol namely adiposity-associated dyslipidemia (Schilcher et al., 2021) are the different types of chronic diseases developed and associated with obesity, and controlling the BMI levels is critical to lowering the incidence and severity of these conditions. Systolic and diastolic blood pressure were significantly associated with increased BMI in the univariate regression analysis, in line with a study conducted in China revealed that there was a significant relationship between systolic (p=0.01) and diastolic blood pressure (p<0.001) and BMI (Wang et al., 2023). Diabetes was found to be significantly associated with increased BMI, this finding is consistent with a study among adults in India, indicating that 46% of diabetic patients have a BMI greater than 25 kg/m2, as compared to a proportion of 18% of non-diabetics (Gupta, 2020). Moreover, subjects who are following a particular diet termed as "special diet" may engage in unhealthy eating habits, such as binge eating (Yan et al., 2023) or emotional eating (Jezewska-Zychowicz et al., 2020), which leads to weight gain and increases the BMI resulting in overweight or obesity. The adherence level to a special diet is associated with an augmented impact on mood (Firth et al., 2020) which can result in the development of psychiatric disorders and eating habits changes, worsening stress levels (Hill et al., 2022), and affecting weight management, eventually resulting in an increased BMI (Bremner et al., 2020).

Ethnicity was significantly associated with increased BMI, and Indians have the highest mean BMI score, which highlights that these variations in BMI across different ethnic groups may be caused by genetic (Saqlain et al., 2022), cultural (Cockerham, 2022), and dietary differences (Zurita et al., 2021) among these distinctive ethnic groups. Different ethnic groups may have varying dietary habits (diets traditionally high in sodium-rich foods) and genetic predispositions that influence both urinary sodium excretion and BMI (Mohammadifard et al., 2023). In line with a study conducted among adults aged ≥ 19 years, 24-urinary sodium was associated with increased body weight, BMI, and waist circumference (Mohammadifard et al., 2023). Certain occupations may influence dietary choices, potentially increasing sodium intake due to stress, sedentary nature, or access to healthy food due to socio-economic status, leading to weight gain and higher BMI (Craig et al., 2023) and those with higher sodium intake have greater susceptibility to being overweight or obese (Mohammadifard et al., 2023). Urinary sodium was associated with increased BMI and body fat percentage (Feng et al., 2021).

Patients with heart disease or stroke may have higher urinary sodium excretion due to medication consumption such as diuretics and the presence of conventional risk factors such as hypertension, dyslipidemia, and insulin resistance (Iyyappan & Maragatham, 2024), potentially influencing BMI (Ramos-Arellano et al., 2020).

CONCLUSION

The findings from this study revealed the mean BMI score significantly increased across tertiles, indicating that higher urinary sodium was associated with increased BMI. The presence of distinctive medical conditions was significantly associated with increased BMI, indicating that these findings underscore the significance of reducing sodium consumption and advocating for a low-sodium diet through the implementation of public education, awareness, policy changes, community support and reducing the accessibility and conveniences of sodium-rich products to overcome obesity and its associated health complications. Precisely, public health initiatives that support healthy weight management and lower the risk of related chronic diseases may benefit from these findings. A wider geographical coverage is recommended to improve the statistical power and generalizability of results within the study population.

AUTHOR CONTRIBUTIONS

Vaidehi Ulaganathan made substantial contributions to the conception and design of this manuscript. The acquisition, analysis, and interpretation of the data for this project was done by Digsha Augundhooa, Madihah Muhammad Royani and Mahla Chambari. The manuscript was drafted by Vaidehi Ulaganathan and Digsha Augundhooa. It was critically revised for important intellectual content by Digsha Augundhooa, Safiya Abdullahi Nuur, Baskaran Gunasekaran, Tanima Bhattacharya and Sree Vamsee Chintapalli. Vaidehi Ulaganathan and Baskaran Gunasekaran conducted the student supervision for this study and actively participated in the final approval of the manuscript. The research management and funding acquisition was done by Vaidehi Ulaganathan. All the authors agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are well addressed.

ETHICS APPROVAL

Ethical approval was obtained from UCSI University Institutional Ethics Committees (IEC-2021-FAS-030) and the Medical Research and Ethics Committee (MREC) (NMRR ID-22-01916-6AB (IIR)).

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CONFLICT OF INTEREST

The authors declare no conflict of interest in this work.

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