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Blood Pressure Association with Sodium Intake from Snacks in Undergraduates

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ABSTRACT

Processed foods are major contributors to the population's dietary salt intake. Sodium intake is related to several adverse health outcomes, such as hypertension, cardiovascular diseases, and death. The intake of high sodium processed foods as snacks has gone up worldwide. The aim of the study was to analyze the association between blood pressure (BP) values and sodium intake from snacks. The mean weekly consumption of snacks was evaluated in 1500 randomly selected undergraduate aged 16-24 years by a food frequency questionnaire; their anthropometrics and BP values were measured by trained researchers. The mean age, metabolic equivalent of activity (METs), body mass index (BMI) and mean sodium intake from snacks per day were; 20.10±1.44 years, 25.51±10.03 METs h/week, 24.86±4.80 kg/m^2 and 1.5 g/day respectively. Systolic blood pressure (SBP) ranged between 104.43±4.89mmHg and 137.27±16.71mmHg while the diastolic blood pressure (DBP) ranged from 71.24±7.83-83.11±12.03 mmHg. The SBP and DBP significantly increased from the lower to the higher tertile of sodium from snacks and with increasing frequency of salty snacks consumption ($p<0.001$). In the multiple logistic regression model, being in the highest SBP quartile (≥115mmHg) was significantly associated with consumption of sodium from snacks (odds ratio (OR) =8803.14; 95% confidence interval (CI) 381.18-203301.7; p =0.000), age, gender and body mass index. Also, being in the highest DBP quartile (≥70mmHg) was significantly associated with consumption of sodium from snacks (odds ratio (OR) =2.84; 95% confidence interval (CI) 1.41-5.69; P =0.003), age, body mass index, but not with gender. The study has shown that sodium intake from snack, daily frequency of consumption of salty snacks were significantly associated with BP values among the students, independently of BMI. Public education and social marketing are needed to motivate the undergraduates to choose healthier snacks with lower sodium content.

Keywords: Blood pressure, Snacks, Sodium intake, hypertension, undergraduates

INTRODUCTION

High blood pressure remains one of the main public health challenges in developed as well as in developing countries. The behavior of the high blood pressure (BP), in the initial phases of life, has shown a strict relationship with hypertension in adulthood [1, 2].Elevated arterial blood pressure (BP) in childhood and adolescence predisposes to hypertension in the adulthood [3] and has been linked with an increased risk of untimely death and early cardiovascular abnormalities, such as left ventricular hypertrophy and initial atherosclerotic lesions [4-7].

The prevalence of hypertension in Africa was reported to be at 46%, followed by America at 35% [8]. Hypertension has continued to increase steadily since the year 2000 [9, 10, 11] especially in low-and middle-income countries [8]. Between 60 and 100% of the disability-adjusted life-years in sub-Saharan African population is attributed to this burden [12]. Hypertension had been previously known as a disease for adults of 40 years or older. However, it is becoming popular in children and adolescents [13, 14]. In the United States, an estimated 4% of adolescents between 12 and 19 years are

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hypertensive [8] compared to 9·5% of a similar age-group of 13 to 19 year-olds in Africa [9]. Prevalence of hypertension in adolescents is quite variable ranging from 3 to 40% [10, 11, 12] in the respective countries such as United states of America, India, China, Hong Kong among other. In a current meta-analysis of blood pressure (BP) surveys in Nigeria, the documented overall prevalence of hypertension was 28.9% (95% CI 21.1–32.8%), with a prevalence of 29.5% (95% CI 24.8–34.3%) among men and 25.0% (95% CI 20.2–29.7%) among women [16].

Consumption of high sodium foods and overweight/obesity are known major risk factors for hypertension [17, 18]. Association between salt intake and BP has been established in adults [19-21] but the relationship is still controversial at younger ages [22, 23]. The intake of salt in children and adolescents has continued to grow globally owing to increased consumption of high sodium processed foods rather than natural foods, which are low in sodium and high in potassium [23]. In a study on US persons aged 8–18 years; the intake of sodium has been estimated to be on average 3.387 g/day, with an increasing intake with age [25]. In Italy, the sodium intake in individuals aged 11 years has been estimated to be about 3 g/day in a study conducted in 1990s [26]. These intakes were twofold higher than the recommended daily sodium intake in this age range (1.5 g/day) [26]. However, information on sodium intake among persons in these age rang especially the undergraduates is scarce in Nigeria.

Manufactured foods and foods eaten away from home constitute the major part of dietary sodium [26].In reality, some of the main sources of sodium in children's diets globally are pizza, chips and sandwiches that are regularly eaten as snacks between meals [28, 29].Snacking has become a popular habit among children and teenagers [29] even among undergraduates in higher institution, snacks consumption has being on the rise. Snacking trends are moving toward three snacks per day, and about 27% of the daily caloric intake of children is coming from snacks[30].The goal of the present cross-sectional study was to investigate the association between arterial BP values, the sodium content of the snacks and the frequency of consumption of salty snacks among 1500 undergraduates aged 16-24 years.

MATERIALS AND METHODS

PARTICIPANTS

The participants were undergraduates of Afe Babalola University, Nigeria. About 1500 students were randomly selected from each of the colleges in the university. The students were administered questionnaires on health status, exercise levels, present and past illness and medications. Food-frequency questionnaire evaluating the mean weekly frequency of 10 food items was added to the questionnaire. The students signed consent forms for study participation. The study protocol was approved by the University Ethical Committee, and the processes were in compliance with the Helsinki Declaration principles.

MEASUREMENTS

Weight, height, arterial blood pressure were measured in all the participants; weight was measured in kg using a bathroom scale while the height was measured in meter using a tape with the participants wearing light clothes and no shoes. The body mass index values were obtained in kg/m^2, subjects whose BMI was ≥ 25 were classified as overweight.

The arterial blood pressure values were measured from the left arm in a sitting position, after about 5 minutes of rest with a Medical Lloyds-pharmacy digital blood pressure monitor with appropriate cut off sizes, the measurement was taken by the invigilator of the field survey, the systolic and diastolic blood pressure was measured using the blood pressure monitor. Pulse pressure was the difference between systolic blood pressure and diastolic blood pressure. The participants were divided into quartiles of systolic blood pressure and diastolic blood pressure.

The mean weekly exercise level was calculated as the product of duration and frequency of each activity (in hours/week), weighted by an estimate of the metabolic equivalent of the activity (MET) and summed for the activities performed. The whole cohort was divided into tertiles of exercise and the individuals were classified as; sedentary, moderately active and active. The cut of points in the whole cohort were respectively; ≤ 10, 11-29, ≥ 30 MET h/week. Exercise levels were therefore expressed as MET h/week.

The food-frequency questionnaire evaluated the mean weekly frequency consumption of 10 items and was developed to evaluate the mean weekly snacks consumption. A snack was defined as an eating

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occasion not included in breakfast, lunch or dinner; in line with literature. (Hampl et al, 2003). The respondents were asked to indicate how many times a week they consumed each snack food included in the list by choosing one of three different ranges of consumption frequency (1-2/week; 3-5/week; ≥6/week). The items included were; plantain chips, doughnut, pure bliss biscuit, samosa, spring roll, chin chin, cake, parago candy, meat pie and gala.

The sodium intake from snacks was estimated by multiplying the estimated weekly food consumption of each item by its value of sodium concentration obtained from the analysis of sodium content of each sample in a laboratory. The sodium contents of all the items consumed were summed and divided by seven to obtain the mean daily sodium intake from snacks.

The mean daily sodium intake was then divided into three tertiles (<1.13g/day, 1.13-1.163g/day, >1.63g/day). Furthermore, as salty snacks were considered those whose sodium content per portion was ≥30g ie. Savory snacks. The weekly consumption of salty snacks were summed and then divided by 7 to obtain the mean daily frequency intake. Three categories of salty food frequency consumption were considered; 0-1, >1-2, >2.

DETERMINATION OF SODIUM CONTENT OF SNACKS

The ash of each sample obtained was digested by adding 5ml of 2 MHCl to the ash in the crucible and heat to dryness on a heating mantle. 5ml of 2 MHCl was added again, heat to boil, and filtered through a Whatman No. 1 filter paper into a 100ml volumetric flask. The filterate was made up to mark with distilled water stopped and made ready for reading of concentration of Sodium on the Jenway Digital Flame Photometer(PFP7 Model) using the filter corresponding to the mineral.

The concentration of sodium was calculated using the formula:

$$\%Na = \frac{\text{Meter Reading(MR)} \times \text{Slope} \times \text{Dilution factor}}{10000}$$

STATISTICAL ANALYSIS

Normality distribution of data was checked by the Kolmogorov-Smirnov normally test. Exercise level, expressed as METs h/week, did not show a normality distribution, and differences among groups for this variable were analyzed by the Kruskal-Wallis test. The ANOVA and the Chi-square (χ2)-test were performed to assess the differences respectively in the continuous and categorical variables across tertiles of sodium content and across categories of frequency of salty snacks consumption, and between quartiles of SBP and DBP. A logistic regression analysis was used to estimate the relative risk of being in the highest quartile of SBP or DBP and the sodium content of snacks, after adjusting for age, sex, and BMI. The food frequency questionnaire data, socio demography data and anthropometry measurements were loaded on the statistical package for the social sciences (SPSS). The ANOVA test was performed to assess the differences respectively in the continuous and variables across categories of frequency of salty snacks consumption and between quartiles of systolic blood pressure and diastolic blood pressure.

RESULTS

Table 1 summarizes the features of the students who participated in the study. Average age of the students was 20.10±1.44 years. Majority of the participants were moderately active as shown by the result of metabolic equivalent of activity of 25.51±10.03 METs h/week. Mean body mass index of the participants was 24.86±4.80 kg/m^2. The estimated mean sodium intake from snacks per day was 1.50±0.62 g/day. Total sodium from snacks per day, metabolic equivalent of activity, weight, height, and BMI, SBP, DBP and pulse pressure significantly differed among the categories of sodium content (Table 2) and frequency of salty snacks consumption (Table 3). Age, SBP and DBP increased with increasing sodium intake from snacks and with increasing frequency of salty snacks consumption (Table 2 & 3).

Higher sodium intake from snacks, frequency of consumption of salty snacks, height, weight and BMI were significantly associated with participants in the highest SBP quartile (Table 4). Also, participants in the highest DBP quartile showed significantly higher sodium intake from snacks, frequency of consumption of salty snacks, height, weight and BMI (Table 5).

Being in the highest systolic BP quartile or highest diastolic BP with sodium from snacks, age, gender and body mass index is shown in Table 6. In the multiple logistic regression model, being in the

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highest SBP quartile was significantly associated with consumption of sodium from snacks (odds ratio (OR) =8803.14; 95% confidence interval (CI) 381.18-203301.7; *P =0.000*), age, gender and body mass index. Also, being in the highest DBP quartile was significantly associated with consumption of sodium from snacks (odds ratio (OR) =2.84; 95% confidence interval (CI) 1.41-5.69; P =*0.003*), age, body mass index, but not with gender.

Table 1: Characteristics of the sample analyzed

	Sample study for Snacks
Number	1500
Age (years)	20.10±1.44
Females (%)	1070 (71.3)
Ethnicity (%)	
Yoruba	470 (31.33)
Hausa	50(3.33)
Igbo	340 (22.67)
Others	640(42.67)
Metabolic equivalent of activity(METs h/week)	25.51±10.03
Weight (kg)	65.90±14.10
Height (m)	1.63±0.10
BMI (kg/m^2)	24.86±4.80
Mean sodium intake (g/day)	1.50±0.62

Abbreviation: BMI= Body mass index

Table 2: **Characteristics of the participants by the sodium content of snacks (first tertile the lowest, third tertile the highest)**

	First tertile	Second tertile	Third tertile	*p- value*
Number	580	370	550	
Total sodium from snack(g/day)	0.86±0.13	1.49±0.17	2.12±0.45	<0.001
Female (%)	30.7	21.3	19.3	0.001
Metabolic equivalence of activity(MET h/week)[b]	560 (37.3)	390 (26)	550 (36.7)	0.051
Age(year)	19.74±1.29	20.05±1.35	20.42±1.57	0.42
Weight(kg)	60.31±13.81	60.89±13.79	70.40±12.69	<0.001
Height(m)	1.60±0.0.068	1.61±0.078	1.66±0.079	0.001
BMI (kg/m^2)	23.33±4.83	26.16±5.12	25.62±4.13	0.006
Systolic BP	104.43±4.89	122.16±17.13	137.27±16.71	<0.001
Diastolic BP	71.24±7.83	76.70±8.63	83.11±12.03	<0.001
Pulse pressure	33.19±8.81	45.19±19.86	43.71±18.39	<0.001

Mean ± SD (all such values), BMI=body mass index, BP=blood pressure, total sodium from snacks (both salty and non-salty), use of ANOVA test, data obtained from 1500 participants. [b]Kruskal–Wallis analysis

Table 3: Characteristics of participants by the daily frequency of consumption of salty snacks

	0 -1	**>1-2**	**>2**	***p value***
Number	470	270	760	
Total Sodium From Snack(g/day)	0.83±0.11	1.19±0.22	1.98±0.45	<0.001
Female (%)	35.5	22.4	42.1	0.003
Metabolic Equivalence of Activity(MET h/week)[b]	47(31.3)	27(18)	76(50.7)	0.062
Age(year)	19.57±1.35	19.96±1.32	20.41±1.45	0.006
Height(m)	1.60±0.069	1.62±0.071	1.64±0.082	0.016
BMI (Kg/m^2)	23.41±5.02	24.12±4.97	26.04±4.33	0.008
Systolic BP	104.29±3.43	108.56±6.38	135.35±17.23	<0.001
Diastolic BP	70.55±7.53	75.41±9.41	81.43±11.36	<0.001
Pulse Pressure	33.74±7.95	33.15±10.63	53.62±19.79	<0.001

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Mean ± SD (all such values), BMI=body mass index, BP=blood pressure, total sodium from snacks (both salty and non-salty), use of ANOVA test, data obtained from 1500 participants. [b]Kruskal–Wallis analysis

Table 4: Characteristics of participants by systolic blood pressure (the higher quartile vs the lower quartile)

	Systolic blood pressure >115mmHg	Systolic blood pressure ≤115mmHg	*p* value
Numbers	770	730	
Sodium from snacks (g/day)	1.97±0.46	0.96±0.24	< 0.001
Frequency of salty snacks 0-1 >1-2 >2	10(0.67%) 0(0%) 760(50.67%)	460(30.67%) 270(18%) 0(0%)	<0.001
Female (%)	51.33	48.67	<0.001
MET h/week [b] ≥30 MET h/week 11-29 MET h/week ≤10 MET h/week	 370(24.67%) 260(18%) 140(9.33%)	 510(34%) 130(8.67%) 90(6%)	0.023
Age	20.40±1.44	19.71±1.35	0.003
Weight	70.27±12.74	61.25±13.99	< 0.001
Height	1.64±0.082	1.61±0.069	0.007
BMI(kg/m^2)	23.04±4.29	23.64±5.01	0.002
SBP (mmHg)	135.00±17.75	105.92±5.12	< 0.001

Mean ± SD (all such values), BMI=body mass index, BP=blood pressure, total sodium from snacks (both salty and non-salty), use of ANOVA test, data obtained from 1500 participants. [b]Kruskal–Wallis analysis

Table 5: Characteristics of participants by diastolic blood pressure (the higher quartile vs the lower quartile)

	Diastolic blood pressure >70mmHg	diastolic blood pressure ≤70mmHg	*p* value
Numbers	1100	400	
Sodium from snacks (g/day)	1.58±0.64	1.19±0.49	0.001
Frequency of salty snacks 0-1 >1-2 >2	 270(18%) 190(12.7%) 670(42.7%)	 200(13.3%) 80(5.3%) 120(8%)	<0.001
Female	73.33%	26.67%	<0.001
MET h/week[b] ≥30 MET h/week 11-29 MET h/week ≤10 MET h/week	 550(36.67%) 350(23.33%) 200(13.33%)	 33(22%) 4(2.67%) 12(8%)	0.023
Age	20.25±1.49	19.58±1.13	0.003
Weight	68.59±14.05	58.43±11.26	< 0.001
Height	1.64±0.082	1.59±0.059	0.007
BMI(kg/m^2)	25.59±4.76	22.87±4.35	0.002
SBP (mmHg)	122.97±18.79	155.00±20.99	< 0.001
DBP (mmHg)	81.21±9.07	65.00±6.18	< 0.001
Pulse pressure	41.49±17.24	49.80±20.22	< 0.001

Mean ± SD (all such values), BMI=body mass index, BP=blood pressure, total sodium from snacks (both salty and non-salty), use of ANOVA test, data obtained from 1500 participants. [b]Kruskal–Wallis analysis

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Table 6: **Association of being in the highest systolic BP quartile (upper part) or being in the highest diastolic BP quartile with sodium from snacks in a multiple logistic regression model**

	OR	95% CI	P-value
Being in the highest systolic BP quartile			
Age (years)	1.43	1.12-1.83	0.004
Females	3.43	1.59-7.39	0.002
BMI(kg/m^2)	1.12	1.04-1.20	0.003
Sodium from snacks (g/day)	8803.136	381.18-203301.7	0.000
Being in the highest diastolic BP quartile			
Age (years)	1.41	1.08-1.86	0.013
Females	0.54	0.22-1.28	0.16
BMI(kg/m^2)	1.15	1.05-1.26	0.003
Sodium from snacks (g/day)	2.84	1.41-5.69	0.003

BMI= Body mass index

DISCUSSION

This study investigated the association between arterial BP values, the sodium content of the snacks and the frequency of consumption of salty snacks among undergraduates aged 16-24 years. This study showed that snacking contributes significant amount to total sodium intake among the students. Besides, we noticed a positive significant relationship between BP and both sodium intake from snacks and the frequency of consumption of salty snack foods. The intake of sodium from snacks (evaluated as the frequency of salty snacks) and BMI were individually associated with values of SBP and DBP, and the association of sodium intake from snacks with BP remained significant also when BMI was included in the model.

Our study established a considerable relationship between sodium intake from snacks and increased SBP and DBP. Numerous studies have examined the association between total sodium intake and BP in adolescents [22, 23] very few studies have assessed the influence of sodium from snacks to the best of our knowledge. The National Diet and Nutrition Survey for young people, a UK nationally representative sample of 1658 persons aged 4–18 years, established that an increase of 1 g/day in salt intake was linked with an increase of 0.4mmHg in SBP and 0.6mmHg in pulse pressure [31].Sodium intake was related with SBP and the risk of prehypertension/hypertension among 6235 8–18-year-old participants from the National Health and Nutrition Examination Survey [25]. Ina meta-analysis of 10 trials in children and adolescents, it was confirmed that a 42% cut in salt intake, corresponding to a decrease of approximately 3 g/day in salt intake (1.2 g/day of sodium), bring about a drop in SBP of 1.2mmHg [23]. Our study found strong relationship between the amount of sodium intake from snacks and the highest SBP and DBP quartiles. We also found a positive relationship between SBP and DBP values and BMI, and this is in line with previous studies [32, 33]. Snacking could contribute both to increase BMI and BP values, Ponzo et al[34].Earlier studies have found a direct association between snacking and weight gain risk [35, 36, 37].Likewise ,high-sodium snacks are positively associated with the intake of sugar-sweetened beverages that considerably increase the intake of carbohydrates and have been associated with children/adolescent obesity[38]. Similarly, our overweight/obese participants showed significantly higher sodium intake from snacks and increased frequency of salty snacks consumption. Also, both BMI and sodium intake were significantly associated with the highest SBP and DBP quartiles in the logistic regression models, signifying that both were individually associated with BP quartiles, without mutual interference. Yang et al [39] stated that the correlation between BP values and salt intake is stronger among persons with overweight or obesity. Generally, adiposity has a central role on BP values [40]and obesity or overweight are well-known risk factors for arterial hypertension in the adults as well as in the young people [39 41].

It is a tradition among adolescents to consume snacks between meals [29, 35]. Snacking may not be detrimental, nevertheless the quality of the snacks, Ponzo et al[34]. Eating the right amount of servings of fruits and fresh vegetables as daily snacks would increase fiber and decrease fat, sugar and sodium intake to reach the recommended nutritional goals[31, 35]. Otherwise, unwholesome snacking may have a role in the development of overweight/obesity and hypertension. However, some studies could not find any association between overweight and snacking [42, 43], stating that obese adolescents eat no more ‘junk’ food than their non-obese colleagues.

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However, it is imperative to exercise caution when interpreting the results of this cross-sectional design because of certain limitations. The likelihood of residual confounding cannot be rule out since there is no recent agreement about the definition of a snack. We defined snack as each eating occasion outside meals based on the existing definition by previous studies [41, 45, 46].The probable sodium intake may be misconstrued, because salt added during cooking or eating were not taken into cognizance. It is difficult to correctly measure the quantity of sodium assumed and the 24-hurinary sodium excretion was not measured. Also, the food-frequency questionnaire only evaluated the mean weekly frequency of consumption of snacks.

CONCLUSION

The study has shown that sodium intake from snack, daily frequency of consumption of salty snacks were significantly associated with BP values among the students, independently of BMI.Sodium from snacks could be modified in interventional trials to reduce BP values in adolescents

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