Blood pressure and sodium intake from snacks in adolescents.

DOI:10.1038/ejcn.2015.9

(Article begins on next page)

Blood pressure and sodium intake from snacks in adolescents.

Ponzo V, RD[1], Ganzit GP, MD[2], Soldati L, PhD[3], De Carli L, MD[1], Fanzola I, RD[1], Maiandi M, PhD[1], Durazzo M, MD[1], Bo S, MD[1].

[1]Department of Medical Science, University of Torino, Torino, Italy

[2]Sport Medicine Institute of Torino, Torino Italy

[3]Department of Health Sciences, University of Milano, Milano, Italy

Word count: abstract 244; text 3439; 5 tables

Running title: blood pressure values and sodium from snacks

Corresponding author: Simona Bo, Department of Medical Science, University of Torino, Corso Dogliotti 14, 10126 Turin, Italy Telephone +(39)(011)6336036 Fax+(39)(011)6634751 E-mail: simona.bo@unito.it

Conflict of interest: none

Abstract

Background/objectives: The relationship between sodium intake and arterial blood pressure (BP) values in adolescence is still controversial. The intake of high-sodium processed foods as snacks has gone up worldwide. The purpose of the present cross-sectional study was to analyze the association between BP values and sodium intake from snacks. *Subjects/methods:* The mean weekly consumption of snacks was evaluated in 1200 randomly selected adolescents aged 11-13 years by a food-frequency questionnaire; their anthropometric and BP values were measured by trained researchers. A dietary 24-hour food recall questionnaire was randomly given to 400 of the 1200 adolescents. *Results:* Mean sodium intake from snacks was 1.4 g/day. Systolic (SBP) and diastolic BP (DBP) significantly increased from the lower to the higher tertile of sodium from snacks and with increasing frequency of salty snacks consumption. In a multiple logistic regression model, both being in the highest SBP quartile and in the highest DBP quartile were significantly associated with the intake of sodium from snacks (OR=1.48;95%CI 1.14-1.91 and OR=2.17; 1.68-2.79, respectively), the consumption of >2/day salty snacks (OR=1.86; 1.32-2.63 and OR=2.38; 1.69-3.37, respectively) and BMI (OR=1.26;95%CI 1.22-1.31 and OR=1.14;95%CI 1.10-1.18, respectively), but not with age, sex or exercise levels. In the 400 individuals, the average total sodium intake was 3.1 g/day and was significantly higher in individuals belonging to the highest quartile of SBP and DBP. *Conclusions:* Sodium intake from snacks was almost half of the average daily sodium consumption and was significantly associated with BP values in adolescents.

Key words: adolescents, diastolic blood pressure, systolic blood pressure, snacks, sodium intake.

Abbreviations: basal metabolic rate (BMR), body mass index (BMI), diastolic blood pressure (DBP), metabolic equivalent of activity (METs), saturated fatty acids (SFA), simple dietary quality index (SDQI), systolic blood pressure (SBP).

Introduction

High arterial blood pressure (BP) in childhood and adolescence predisposes to hypertension in the adulthood[1], and has been associated with an increased risk of premature death and early cardiovascular abnormalities, such as left ventricular hypertrophy and initial atherosclerotic lesions[2,3,4,5].

Both the incidence and prevalence of arterial hypertension in children and adolescents are progressively increasing[6]. The current prevalence of hypertension in children worldwide is estimated to be about 1-5% [6,7]; in Italy the prevalence of hypertension and pre-hypertension in individuals aged 6-18 years is 3.5% and 12.8% respectively[8].

Overweight/obesity and high sodium intake are recognized as major risk factors for hypertension[9,10]. A causal relationship between salt intake and BP has been demonstrated in adults[11,12,13] , but the association is still controversial at younger ages[14,15].

The consumption of salt in children and adolescents is worldwide increasing because of the increased intake of high-sodium processed foods instead of natural foods, which are low in sodium and high in potassium[16]. In a study on US individuals aged 8-18 years, the intake of sodium resulted on average 3.387 g/day, with an increasing intake with age[10]. In Italy, the sodium intake in individuals aged 11 years has been estimated to be about 3 g/day[17] in a study conducted in 1990s. These intakes were 2-fold higher than the recommended daily sodium intake in this age range (1.5 g/day)[18] and no recent data are available.

Most of the dietary sodium derives from manufactured foods and foods eaten away from home[19]. In fact, some of the major sources of sodium in worldwide children's diets are pizza, chips, sandwiches that are often eaten as snacks between meals [20,21,22].

Snacking has become a popular habit among children and teenagers[23] even in countries in the Mediterranean area[24] as Italy: in fact in the last decade snack sales have gone up by 57%[25].

Snacking trends are moving toward 3 snacks per day, and about 27% of the daily caloric intake of children is coming from snacks[26].

The purpose of the present cross-sectional study was to analyze the association between arterial BP values, the sodium content of the snacks and the frequency of consumption of salty snacks by a cohort of 1200 individuals aged 11-13 years.

Material and methods

Participants

All the students attending the first year of middle school in Torino (Italy) routinely undergo a health status and physical performance assessment by the Sports Medicine Institute ("Bambini a Torino" project). In Italy, the age at which the students attend the first year of middle school is 11-12 years. However, a few individuals may have failed the exams during their schooling, thus repeating the scholastic year and being 1 year older.

In the scholastic year 2011-2012, 7263 students attended the first year of middle school in Torino. Among them, 6876 participated in the assessment with a participation rate of 94.7%.

A week before the assessment, students were administered questionnaires on health status, exercise levels, present and past illness, and medications by the schoolteachers and were asked to have them filled out by their parents at home. In 1200 students, selected by a simple random sampling, a food-frequency questionnaire evaluating the mean weekly frequency of 19 food items was added to the health questionnaires. By a further simple random sampling, 400 out of the 1200 received also a validated dietary 24-hour food recall questionnaire[27]. The present study was based on the 1200 students.

Children's parents or legal representatives signed a consent form for the study participation. The study protocol was approved by the local Ethical Committee, and the procedures were in compliance with the Helsinki Declaration principles.

Measurements

Weight, height, and arterial blood pressure were measured in all the participants. Weight was measured to the nearest 0.1 kg, and height was measured to the nearest 0.1 cm with a stadiometer (SECA model 711, Hamburg, Germany), with the participants wearing light clothes and no shoes. The body mass index (BMI) percentile values were obtained from the Italian growth charts, referring to Northern/Central Italy percentiles[28]. Subjects who had a BMI ≥85th percentile were classified as overweight/obese.

Arterial BP values were measured from the left arm, in a sitting position, after at least 10 min of rest, with a mercury sphygmomanometer with appropriate cuff sizes (ERKA Perfect-Aneroid, Germany). Two measurements were taken by trained physicians with arm supported at heart level and the values reported were the means of the two. Phase I and V of the Korotkoff sounds were considered as systolic BP (SBP) and diastolic BP (DBP), respectively. Pulse pressure was the difference between SBP and DBP. Participants were divided into quartiles of SBP and DBP.

Data relative to the frequency, duration of each session, and intensity of exercise performed by the participants outside gymnastics classes at school were collected by the questionnaires administered by the parents. Exercise was considered as any planned, structured, and repetitive physical activity performed outside gymnastics classes performed at school. 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[29]. The whole cohort was divided into tertiles of exercise, and individuals were classified as sedentary, moderately active, and active. The cut-off points in the whole cohort were respectively ≤10, 11-29, and ≥30 METs h/week, and were similar to those found in another European cohort of adolescents[30]. Exercise levels were therefore expressed as METs h/week.

Food questionnaires

The parents of participants were asked to complete the 19-item food-frequency questionnaire, while the parents of the 400 randomly selected students completed both the food-frequency and the food recall questionnaire[31]. An instruction sheet was given.

The food-frequency questionnaire evaluated the mean weekly frequency of consumption of 19 items, and was developed by using a previously validated semi-quantitative food-frequency questionnaire[32] to evaluate the mean weekly snacks consumption. Parents should indicate the frequency of consumption of foods consumed as snacks. A snack was defined as an eating occasion not included in breakfast, lunch or dinner, in line with literature[33]. The parents were asked to indicate how many times a week their child 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). If the student consumed a food more than once a day, the parents should specify the frequency for each day; if the subject never consumed a food, the parents must not fill the corresponding item. Items included: biscuits, brioches, cereal bars, candies, desserts, fruit juice, soft drinks, fruits, milk/yoghurt, savory snacks, pizzas, crackers, rusks, potato chips, popcorn, bread, vegetables, cold cut, cheese. For each item, a standard portion was indicated (e.g. 125 ml for yoghurt, 30 g for potato chips, 4 pieces for biscuits, etc.); the parents were asked to indicate the portion in the case it differed from the standard one. No missing cases occurred.

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 food composition database developed by National Research Institute for Food and Nutrition (INRAN)[34]. Then, the sodium contents of all the items consumed were summed and divided by 7 to obtain the mean daily sodium intake from snacks. The mean daily sodium intake was then divided into three tertiles (<1.13 g/day; 1.13-1.63 g/day; >1.63 g/day).

Furthermore, as salty snacks were considered those whose medium sodium content per portion was ≥0.30 g, i.e. savory snacks, pizzas, crackers, potato chips, cheese, and cold cut. This cut-off corresponded to about 20% of the percent daily recommended value for this age range (1.5 g/day), and has been used to define a high-sodium serving[35]. The weekly consumption of salty snacks was 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.

In the 24-hour food-recall questionnaire, the parents were asked to list foods eaten by the students at meals, including snacks; different serving sizes were specified for each item, using commonly used portions; furthermore the use of measuring guides (cups, spoons, glasses) aided respondents in estimating the amounts of foods consumed. The average sodium intake did not include salt added in cooking or at the table. The snacking occasions were reported by the participants' parents, along with a detailed description of the kind, amount, and time of snacks.

During the visit at the Sports Medicine Institute, a skilled dietician interviewed the participants in case of uncertain answers to either the food-frequency questionnaire or the 24h dietary recall, asking them to indicate how often per day and how many days a week they had usually consumed a specific food and its serving size with the aid of sample photos.

The food-recall questionnaire data were loaded on the software Win Food Pro 3 (Medimatica, Colonnella, Teramo, Italy). The estimated basal metabolic rate (BMR) for 10-18-year old individuals was calculated in the 400 participants by the following formula in accordance with Schofield[36]: for males, BMR = 0.068 weight + 0.574 height + 2.157; for females, BMR = 0.035 weight + 1.948 height + 0.837. Then, the estimated energy requirement was calculated by multiplying the BMR by a coefficient corresponding to one of the three exercise levels (sedentary, moderately active, and active), in line with the Italian and European guidelines[37].

Then, the reliability of the reported energy intake was assessed by calculating the ratio of estimated energy intake to predicted BMR: subjects with a ratio <0.88 and >2.72 were classified as under-reporters or over-reporters, respectively[38]: 12/400 under-reporters and 2/400 over-reporters were identified.

Diet quality was evaluated with the simple dietary quality index (SDQI) score, first used in Denmark, comparing saturated fatty acids (SFA) and fiber intake to Danish dietetic recommendations[39]. An adjustment in the dietary fiber estimation was needed for our cohort, because Italian guidelines recommended 2g/MJ for children/adolescents[37]. For each individual, a score was calculated for SFA and dietary fiber, and the minimum and maximum scores for each nutrient were 0 and 100, respectively. For example:

-dietary fiber score: (recommended dietary intake: 2g/MJ)

intake of an individual 1g/MJ; score = 1:2 x 100 = 50; when the individual intake was >=2g/MJ, the score was 100,

-SFA score: (recommended dietary intake <= 10% energy)

intake of an individual 13% energy; score = (1 – (13 -10)/10) x 100 = 70; when the individual intake was <= 10% energy, score = 100; when >20% energy, score = 0.

The SDQI score was the mean of the scores for SFA and fiber (i.e. (50 + 70)/ 2 = 60); the higher was the score, the healthier was the diet[39].

Statistical analysis

Normality distribution of data was checked by the Kolmogorov-Smirnov normally test. BMI percentiles and 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. Additionally, values were log-transformed, thus obtaining a normal distribution, and the log-transformed values were used in the regression model (see below). The ANOVA and the χ^2-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 or the category of salty snacks consumption, after adjusting for age, sex, and log-METs h/week.

Results

Table 1 summarizes the characteristics of the 1200 adolescents and the 400 sub-sample undergoing the medical assessment. There was no difference between the adolescent cohort as a whole (data not shown) and the two randomly selected groups.

The average sodium intake was 3.1±0.9 g/day in the 400 participants submitted to the 24-h food recall. Mean sodium intake from snacks was 1.4±0.6 g/day in the 1200 participants submitted to the food-frequency questionnaire.

Neither percent of energy intake from carbohydrates, proteins, fats (data not shown) and saturated fatty acids, nor total energy, fiber intake and the SDQI score significantly differed among the categories of sodium content (Table 2, left) or frequency of salty snacks consumption (Table 2, right). Age, SBP, DBP increased with increasing sodium intake from snacks and with increasing frequency of salty snacks consumption.

Individuals in the highest SBP quartile showed significantly higher sodium intake from snacks, frequency of consumption of salty snacks, height, weight, BMI and BMI percentiles (Table 3). Similarly, individuals in the highest DBP quartile showed significantly higher sodium intake from snacks, frequency of consumption of salty snacks, height, weight, BMI and BMI percentiles (Table 4).

Participants with BMI≥85^{th} percentile (194/1200; 16.2%) when compared to participants with BMI <85^{th} percentile did show neither a significantly higher sodium intake from snacks (1.41±0.6 *vs* 1.40±0.6, respectively, p=0.75), nor a higher frequency of salty snacks consumption (2.0±0.8 *vs* 1.9±0.8, respectively, p=0.25).

In the 400 individuals submitted to the food-recall questionnaire, total sodium intake increased with increasing sodium intake from snacks (Tab.2) and was significantly higher in individuals belonging to the highest quartile of SBP (Tab.3) and DBP (Tab.4). In those individuals, the results did not change after excluding the 12 under-reporters and the 2 over-reporters.

In a multiple logistic regression model, both being in the highest SBP quartile and in the highest DBP quartile were significantly associated with the intake of sodium form snacks, the frequency of salty snacks consumption and BMI, but not with age or sex or METs h/week (Table 5). In the subgroup of 400 individuals, the highest SBP quartile (OR=1.13; 95%CI 1.01-1.62; p=0.04) and the highest DBP quartile (OR=1.33; 95%CI 1.03-1.71; p=0.03) were significantly associated with total sodium intake in the same model.

Discussion

We found that snacking has a considerable effect on total sodium intake since about half of the total sodium in the evaluated adolescents came from snacks. Moreover, we observed a positive significant association between BP and both sodium intake from snacks and the frequency of consumption of salty snack foods. Both the intake of sodium from snacks (either evaluated as a quantity or the frequency of salty snacks) and BMI were independently 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.

Intriguingly, no significant difference was evident among categories of sodium content and salty snacks consumption and intake of energy, nutrients and diet quality as evaluated by the SDQI index in the subgroup of participants submitted to the 24-h food recall.

Daily sodium intake of participants was 2-fold higher than that recommended and was in line with the mean consumption previously reported in Italian children[17], but no data on sodium intake from snacks were until now available. Snacks (such as chips, baked goods, candy, etc.) are usually high-sodium, high-fat and high-sugar foods, and contribute to degrade the diet quality of children and adolescents[32,40]. The finding that about half of the daily sodium intake derives from snacks is new and prompts towards educational campaigns in order to sensitize adolescents as well as parents and teachers with regard to this topic.

We found a significant association between sodium intake from snacks and increased SBP and DBP. The relationship between total sodium intake and BP in adolescents has been investigated by several studies[14-15] , but no study was specifically focused on the impact of sodium from snacks, to the best of our knowledge.

The National Diet and Nutrition Survey for young people, a study carried out in a UK nationally representative sample of 1658 individuals aged 4-18 years, found that an increase of 1 g/day in salt intake was associated with an increase of 0.4 mmHg in SBP and 0.6 mmHg in pulse pressure[41]. Sodium intake was associated with SBP and the risk of pre-hypertension/hypertension among 6235 8-18 years old participants from the National Health and Nutrition Examination Survey[10]. A meta-analysis of 10 trials in children and adolescents demonstrated that a 42% reduction in salt intake, which is equivalent to a decrease of approximately 3 g/day in salt intake (1.2 g/day of sodium), causes a fall in SBP of 1.2 mm Hg[15] .

In our subsample of 400 individuals, a significant direct association was found between total sodium intake and the highest SBP and DBP quartiles. Nevertheless, not all authors have observed a linear relationship between BP and dietary sodium intake in children/adolescents. Howe[42] reported no significant change in BP values between 11-14 year old students with high-sodium intake and increased sodium excretion with respect to students on low-sodium diets. In a randomized crossover trial, Cooper[43] found that 24 days of sodium restriction was ineffective in changing BP values in normotensive adolescents. Finally, Yang[10] reported that the association between BP values and salt intake is stronger among individuals with overweight or obesity. It is well known that adiposity plays a crucial role on BP values[44] and obesity or overweight are recognized as risk factors for arterial hypertension in the adults as well as in the young people[9,10]. In our study, we found a positive relationship between SBP and DBP values and BMI, in line with literature[6,45]. Snacking could contribute both to increased BMI and increased BP values. Prospective studies found a direct association between snacking and weight gain risk[24,46,47]. Moreover, high-sodium snacks are positively associated with the consumption of sugar-sweetened beverages that considerably increase the intake of carbohydrates and have been associated with children/adolescent obesity[48]. However, our overweight/obese participants did not show either a significantly higher sodium intake from snacks or an increased frequency of salty snacks consumption, and both BMI and sodium intake remained significantly associated with the highest SBP and DBP quartiles in the logistic regression models, suggesting that both were independently associated BP quartiles, without reciprocal interference.

Eating snacks between meals has become a very common habit in adolescents[23,24]. It is possible that snacking itself may not be harmful, but rather the quality of the snacks. If fruits and fresh vegetables are consumed as daily snacks, it would be easier to increase fiber and decrease fat, sugar and sodium intake to reach the recommended nutritional goals[32,39]. Otherwise, unhealthy snacking may have a role in the development of overweight/obesity and hypertension. Other studies have however failed to find a relationship between overweight and snacking[49,50], reporting that obese adolescents eat no more "junk" food than their non-obese peers.

This remains a highly controversial topic; our results suggest another reason why snacking deserves more research: because it might have a role on BP values in pediatric subjects.

The limitations of a cross-sectional design should be considered in the interpretations of the results of this study. The possibility of residual confounding cannot be excluded. There is no current consensus about the definition of a snack. As most studies[32,39,51], we based our definition on a temporal criterion and we defined as snack each eating occasions outside meals.

The estimated sodium intake may be underestimated, since it did not include the salt added during cooking or eating. It is difficult to precisely quantify the amount of sodium assumed and the 24-h urinary sodium excretion was not measured. However, in developed countries, the amount of salt discretionarily added to food is small and the majority of salt intake comes from salt added to food by the food industry[19]. In consideration of the rough estimation of sodium intake, the frequency of consumption of salty snack foods has been evaluated; the comparability of the results by the two methods is reassuring.

Finally, the limitations of the food questionnaires should be recognized. The food-frequency questionnaire evaluated the mean weekly frequency of consumption of snacks; the 24h dietary recall may be inadequate to evaluate the individual usual eating pattern and we have the data of one third of the evaluated individuals. The day (week day or week-end day) of the dietary recall compilation was not predefined. However, the 24h dietary recall is usually employed for characterizing habits in groups of adolescents[52,53]. Furthermore, the participants themselves were interviewed by an experienced dietician in the case of uncertain answers. In all of these cases, no considerable discrepancy was found between the measures reported by the parents and the interviewed participants.

The strengths of this study were the measurement of all the anthropometric variables by two trained researchers, and the finding that participants were similar to all the adolescents living in Torino with the same age-range.

Conclusion

Sodium intake from snacks represented almost half of the average daily consumption of sodium and was significantly associated with increased BP values in adolescents, independently of BMI. Sodium from snacks could be a modifiable factor worthy to be tested in interventional trials to reduce BP values in the younger.

Acknowledgements

Valentina Ponzo participated in the conception and design of the study, supervision of data collection, data analysis, interpretation of the findings of the study, manuscript writing and revision. Gian Pasquale Ganzit participated in the data analysis, interpretation of the findings, manuscript writing and revision. Laura Soldati participated in the data collection, interpretation of the findings, and manuscript revision. Luca De Carli participated in the data analysis, interpretation of the findings of the study and manuscript revision. Ilaria Fanzola participated in the data collection, interpretation of the findings of the study and manuscript revision. Maria Maiandi participated in the data collection, interpretation of the findings of the study and manuscript revision. Marilena Durazzo participated in the data analysis, interpretation of the findings of the study and manuscript revision. Simona Bo participated in the conception and design of the study, interpretation of the findings of the study, manuscript writing and revision.

All authors have read and approved the final manuscript.

Conflict of interest

The authors declare no conflict of interest.

References

(1) Sugiyama T, Xie D, Graham-Maar RC, Inoue K, Kobayashi Y, Stettler N.

Dietary and lifestyle factors associated with blood pressure among U.S. adolescents. *J Adolesc Health* 2007; **40**: 166-172.

(2) Carretero OA, Oparil S. Essential hypertension. *Circulation* 2000; **37**: 268-274.

(3) Chen X, Wang Y. Tracking of blood pressure from childhood to adulthood: a systematic review and meta-regression analysis. *Circulation* 2008; **117**: 3171–3180.

(4) Berenson GS. Childhood risk factors predict adult risk associated with subclinical cardiovascular disease. The Bogalusa Heart Study. *Am J Cardiol* 2002; **90**: 3L–7L.

(5) Sundström J, Neovius M, Tynelius P, Rasmussen F. Association of blood pressure in late adolescence with subsequent mortality: cohort study of Swedish male conscripts. *BMJ* 2011; **342**: d643.

(6) Sorof JM, Lai D, Turner J, Poffenbarger T, Portman RJ. Overweight, ethnicity, and the prevalence of hypertension in school-aged children. *Pediatrics* 2004; **113**: 475–482.

(7) McNiece KM, Poffenbarger TS, Turner JL. Prevalence of hypertension and pre-hypertension among adolescents. *J Pediatr* 2007; **150**: 640–644.

(8) Pileggi C, Carbone V, Nobile C, Pavia M. Blood pressure and related cardiovascular disease risk factors in 6–18 year-old students in Italy. *J Paediatr Child Health* 2005; **41**: 347-352.

(9) Spagnolo A, Giussani M, Ambruzzi AM, Bianchetti M, Maringhini S, Matteucci MC, et al. Focus on prevention, diagnosis and treatment of hypertension in children and adolescents. *Ital J Pediatr* 2013; **39**: 20.

(10) Yang Q, Zhang Z, Kuklina EV, Fang J, Ayala C, Hong Y, et al. Sodium intake and blood pressure among US children and adolescents. *Pediatrics* 2012; **130**: 611-619.

(11) Intersalt Cooperative Research Group. Intersalt: an international study of electrolyte excretion and blood pressure. Results for 24 h urinary sodium and potassium excretion. *BMJ* 1988; **297**: 319-328.

(12) Meneton P, Jeunemaitre X, de Wardener HE, MacGregor GA. Links between dietary salt intake, renal salt handling, blood pressure, and cardiovascular diseases. *Physiol Rev* 2005; **85**: 679–715.

(13) Graudal NA, Hubeck-Graudal T, Jurgens G. Effects of low sodium diet versus high sodium diet on blood pressure, renin, aldosterone, catecholamines, cholesterol, and triglyceride. *Cochrane Database Syst Rev* 2011; CD004022.

(14) Simons-Morton DG, Obarzanek E. Diet and blood pressure in children and adolescents. *Pediatr Nephrol* 1997; **11**: 244–249.

(15) He FJ, Mac Gregor GA. Importance of salt in determining blood pressure in children: meta-analysis of controlled trials. *Hypertension* 2006, **48**: 861–869.

(16) Falkner B, Michel S. Blood pressure response to sodium in children and adolescents. *Am J Clin Nutr* 1997; **65**: 618S-21S.

(17) Leclercq C, Ferro-Luzzi A. Total and domestic consumption of salt and their determinants in three regions of Italy. *Eur J Clin Nutr* 1991; **45**:151-159.

(18) Società Italiana di Nutrizione Umana: http://www.sinu.it/larn/mineral1.asp#SODIO.

(19) Liem DG, Miremadi F, Keast RS. Reducing sodium in foods: the effect on flavor. *Nutrients* 2011; **3**: 694-711.

(20) Drewnowski A, Rehm CD. Sodium intakes of US children and adults from foods and beverages by location of origin and specific food source. *Nutrients* 2013; **5**: 1840–1855.

(21) http://www.inran.it/646/tabelle_di_composizione_degli_alimenti.html

(22) Ovaskainen ML, Reinivuo H, Tapanainen H, Hannila ML, Korhonen T, Pakkala H. Snacks as an element of energy intake and food consumption. *Eur J Clin Nutr* 2006; **60**:494–501.

(23) Larson N, Story M. A review of snacking patterns among children and adolescents: what are the implications of snacking for weight status? *Child Obes* 2013; **9**: 104-115.

(24) Bes-Rastrollo M, Sanchez-Villegas A, Basterra-Gortari FJ, Nunez-Cordoba JM, Toledo E, Serrano-Martinez M. Prospective study of self-reported usual snacking and weight gain in a Mediterranean cohort: the SUN project. *Clin Nutr* 2010; **29**: 323-330.

(25) Astrup A, BovyMW, Nackenhorst K, Popova AE. Food for thought or thought for food?-A stakeholder dialogue around the role of the snacking industry in addressing the obesity epidemic. *Obes Rev* 2006; **7**: 303–312.

(26) Piernas C, Popkin BM. Trends In Snacking Among U.S. *Health Aff* 2010; **9**: 398-404.

(27) Bo S, De Carli L, Venco E, Fanzola I, Maiandi M, De Michieli F, et al. Impact of snacking pattern on overweight and obesity risk in a cohort of 11-13-y adolescents. *J Pediatr Gatroenterol Nutr* 2014; **59**: 465-471.

(28) Cacciari E, Milani S, Balsamo A, Dammacco F, De Luca F, Chiarelli F, et al. Italian cross-sectional growth charts for height, weight and BMI (6-20 y). *Eur J Clin Nutr* 2002; **56**: 171-180.

(29) Ainsworth BE, Haskell WL, Herrrmann SD, Meckes N, Bassett DR Jr, Tudor Locke C, et al. 2011 Compendium of physical activities: a second update of codes and MET values. *Med Sci Sports Exerc* 2011; **43**: 1575-1581.

(30) Pahkala K, Heinonen OJ, Lagström H, Hakala P, Sillanmäki L, Simell O. Leisure-time physical activity of 13-year-old adolescents. *Scand J Med Sci Sports* 2007; **17**: 324-330.

(31) Bo S, Ciccone G, Durazzo M, Gambino R, Massarenti P, Baldi I, et al. Efficacy of antioxidant treatment in reducing resistin serum levels: a randomized study. *PLoS Clin Trials* 2007; e17.

(32) Bo S, Bertino E, Trapani A, Bagna R, De Michieli F, Gambino R, et al. Magnesium intake, glucose and insulin serum levels in pre-school very-low-birth weight pre-term children. *Nutr Metab Cardiov Dis* 2007; **17**: 741-747.

(33) Hampl JS, Heaton CLB, Taylor CA. Snacking patterns influence energy and nutrient intakes but not body mass index. *J Hum Nutr Dietet* 2003; **16**: 3-11.

(34) http://nut.entecra.it/646/tabelle_di_composizione_degli_alimenti.html (in Italian).

(35) http://www.fda.gov/Food/ResourcesForYou/Consumers/ucm315393.htm

(36) Schofield WN. Predicting basal metabolic rate, new standards and review of previous work. *Hum Nutr Clin Nutr* 1985; **39**: S5-S41.

(37) http://www.sinu.it/documenti/20121016_LARN_bologna_sintesi_prefinale.pdf (in Italian)

(38) Goldberg GR, Black AE, Jebb SA, Cole TJ, Murgatroyd PR, Coward WA, Prentice AM. Critical evaluation of energy intake data using fundamental principles of energy physiology: 1. Derivation of cut-off limits to identify under-recording. *Eur J Clin Nutr* 1991; **45**: 569-581.

(39) Biltoft-Jensen A, Fagt S, Groth MV, Matthiessen J, Wachmann HC, Christensen T. The intake of saturated fat and dietary fiber: a possible indicator of diet quality. *Br J Nutr* 2008; **100**: 624-632.

(40) Summerbell CD, Moody RC, Shanks J, Stock MJ, Geissler C. Sources of energy from meals versus snacks in 220 people in four age groups. *Eur J Clin Nutr* 1995; **49**: 33-41.

(41) He FJ, Marrero NM, MacGregor GA. Salt and blood pressure in children and adolescents. *J Hum Hypertens* 2008; **22**: 4–11.

(42) Howe PRC, Cobiac L, Smith RM. Lack of effect of short-term changes in sodium intake on blood pressure in adolescent school children. *J Hypertens* 1991; **9**: 181-86.

(43) Cooper R, Von Horn L, Liuk A. Randomized trial on the effect of decreased dietary sodium intake on blood pressure in adolescents. *J Hypertens* l984; **2**: 36.

(44) Tu W, Eckert GJ, DiMeglio LA, Yu Z, Jung J, Pratt JH. Intensified effect of adiposity on blood pressure in overweight and obese children. *Hypertension* 2011; **58**: 818-824.

(45) Freedman DS, Dietz WH, Srinivasan SR, Berenson GS. The relation of overweight to cardiovascular risk factors among children and adolescents: the Bogalusa Heart Study. *Pediatrics* 1999; **103**:1175–1182.

(46) Francis LA, Lee Y, Birch LL. Parental weight status and girls' television viewing, snacking, and body mass indexes. *Obes Res* 2003; **11**:143-151.

(47) Collison KS, Zaidi MZ, Subhani SN, Al-Rubeaan K, Shoukri M, Al-Mohanna FA. Sugar-sweetened carbonated beverage consumption correlates with BMI, waist circumference, and poor dietary choices in school children. *BMC Publ Health* 2010; **10**: 234.

(48) Grimes CA, Wright JD, Liu K, Nowson CA, Loria CM. Dietary sodium intake is associated with total fluid and sugar-sweetened beverage consumption in US children and adolescents aged 2-18 y: NHANES 2005-2008. *Am J Clin Nutr* 2013; **98**: 189-196.

(49) Bandini LG, Vu D, Must A, Cyr H, Goldberg A, Dietz WH. Comparison of High-Calorie, Low-Nutrient-Dense Food Consumption among Obese and Non-Obese Adolescents. *Obes Res* 2000; **7**: 438–443.

(50) Phillips SM, Baldini LG, Naumova EN, Cyr H, Colclough S, Dietz WH, et al. Energy-Dense Snack Food Intake in Adolescence: Longitudinal Relationship to Weight and Fatness. *Obes Res* 2004; **12**: 461–472.

(51) Keast DR, Nicklas TA, O'Neil CE. Snacking is associated with reduced risk of overweight and reduced abdominal obesity in adolescents: National Health and Nutrition Examination Survey (NHANES) 1999-2004. *Am J Clin Nutr* 2010; **92**: 428-435.

(52) Keast DR, Nicklas TA, O’Neil CE. Snacking is associated with reduced risk of overweight and reduced abdominal obesity in adolescents: National Health and Nutrition Examination Survey (NHANES) 1999-2004. *Am J Clin Nutr* 2010; **92**: 428-435.

(53) Slining MM, Mathias KC, Popkin BM. Trends in food and beverage source among US children and adolescents: 1989-2010. *J Acad Nutr Diet* 2013; **113**: 1683-1

Table 1. Characteristics of the sample analyzed

	Sample studied for snacks	**Sample studied with food record**
Number	1200	400
Age (years)	12.1±0.5	12.1±0.5
Males (%)	51.3	52.0
Ethnicity (%)		
Caucasian	93.5	94.1
African	2.4	2.3
Asian	1.5	1.5
Hispanic	2.6	2.3
Metabolic equivalent of activity (METs h/week)	19.0 (32.0)	18.0 (31.5)
Weight (kg)	45.2±11.3	45.5±11.2
Height (m)	1.50±0.1	1.50±0.1
BMI (kg/m^2)	19.9±4.0	20.0±4.1

Table 2. Characteristics of the participants by the sodium content of the snacks (first tertile the lowest; third tertile = the highest) and the daily frequency of consumption of salty snacks.

	Sodium content of snacks				Daily frequency of salty snacks			
	First tertile	**Second tertile**	**Third tertile**	**P**	**0-1**	**>1-2**	**>2**	**P**
Number	403	403	394		461	336	403	
Total sodium from snacks (g/day)[1]	0.9±0.3	1.3±0.2	2.1±0.4	<0.001	0.9±0.3	1.3±0.2	2.0±0.4	<0.001
Age (years)	12.0±0.5	12.0±0.4	12.2±0.5	<0.001	12.0±0.4	12.0±0.4	12.2±0.5	<0.001
Males (%)	50.4	49.6	54.1	0.41	51.3	47.9	54.1	0.25
Metabolic equivalent of activity[2] (METs h/week)	20.0 (33.0)	20.0 (32.0)	14.5 (26.0)	0.22	21.0 (34.0)	19.0 (32.0)	15.0 (26.0)	0.03
Weight (kg)	45.0±11.3	44.8±10.6	45.8±12.0	0.43	44.6±11.1	45.5±10.8	45.6±12.0	0.33
Height (m)	1.50±0.1	1.50±0.1	1.50±0.1	0.84	1.50±0.1	1.50±0.1	1.50±0.1	0.49
BMI (kg/m^2)	19.9±4.0	19.7±3.7	20.1±4.2	0.36	19.7±3.9	19.9±3.8	20.0±4.2	0.48
BMI percentile[2]	40.0 (58.0)	40.0 (59.0)	40.0 (57.0)	0.99	38.0 (58.0)	44.5 (58.5)	40.0 (57.0)	0.37
BMI≥85thpercentile(%)	15.4	15.4	17.8	0.57	14.5	17.0	17.4	0.46
Systolic BP (mmHg)	107.7±11.6	108.6±12.3	111.6±13.7	<0.001	107.7±10.7	109.3±12.9	111.0±14.1	<0.001
Diastolic BP (mmHg)	64.2±8.7	64.8±9.2	66.5±8.3	<0.001	64.4±7.9	65.6±8.7	66.3±8.5	0.002
Pulse pressure (mmHg)	43.5±8.6	43.3±9.4	45.0±10.3	0.02	43.8±8.1	43.2±9.9	44.7±10.4	0.08
Total kcal[3]	1953.0±413.9	2065.8±448.5	2027.1±469.3	0.10	1982.2±411.6	2048.1±467.3	2023.8±464.2	0.46
SFA (% kcal)[3]	10.6±3.1	10.4±3.0	11.2±3.4	0.12	10.6±3.1	10.3±3.0	11.2±3.4	0.10
Fiber(g/day)[3]	15.8±6.4	15.6±6.0	16.4±5.5	0.62	15.8±6.6	15.7±5.8	16.3±5.5	0.74
SDQI score[3]	74.7±13.2	73.5±14.5	72.6±15.3	0.53	74.1±13.5	74.4±14.3	72.4±15.2	0.51
Total sodium (g/day)[3]	2.0±0.8	2.7±0.7	3.4±0.9	<0.001	2.1±0.7	2.7±0.7	3.4±0.9	<0.001

Mean ±SD (all such values); median (inter-quartile range) (all such values); BMI=body mass index; BP=blood pressure; SFA= saturated fatty acids; SDQI= simple dietary quality index;[1]Total sodium from snacks (both salty and non-salty);[2]Kruskal-Wallis analysis [3]data obtained from 400 participants.

694.

Table 3. Characteristics of the participants by systolic BP values (the higher quartile *vs* lower quartiles).

	Systolic BP>115 mmHg	Systolic BP≤115 mmHg	P
Number	301	899	
Sodium from snacks (g/day)	1.5±0.6	1.4±0.5	0.002
Frequency of salty snack consumption/day			
0-1	30.2	41.2	
>1-2	28.2	27.9	
>2	41.5	30.9	<0.001
Age (years)	12.1±0.5	12.1±0.4	0.09
Males (%)	49.8	51.8	0.55
Metabolic equivalent of activity[1] (METs h/week)	15.0 (32.0)	19.0 (32.0)	0.11
Weight (kg)	53.3±11.8	42.4±9.8	<0.001
Height (m)	1.53±0.1	1.49±0.1	<0.001
BMI (kg/m^2)	22.6±4.2	19.0±3.4	<0.001
BMI percentile[1]	75.0 (52.0)	30.0 (46.0)	<0.001
BMI≥85thpercentile(%)	37.9	8.9	<0.001
Systolic BP (mmHg)	125.3±8.3	103.9±8.7	<0.001
Diastolic BP (mmHg)	72.4±8.5	62.7±7.5	<0.001
Pulse pressure (mmHg)	52.8±8.9	40.9±7.6	<0.001
Total kcal[2]	2004.0±476.1	2016.9±431.8	0.80
Carbohydrates (% kcal)[2]	51.1±14.2	51.2±14.8	0.92
Fat (% kcal)[2]	35.7±10.2	35.9±10.2	0.77
SFA (% kcal)[2]	10.9±3.4	10.7±3.1	0.57
Protein (% kcal)[2]	13.2±3.9	12.9±3.9	0.25
Fiber (g/day)[2]	15.4±6.2	16.1±6.0	0.34
SDQI score[2]	71.7±14.9	74.5±13.9	0.09
Total sodium (g/day)[2]	3.1±1.0	2.6±0.9	<0.001

Mean ±SD (all such values); median (inter-quartile range) (all such values); BMI=body mass index; BP=blood pressure; SFA= saturated fatty acids; SDQI= simple dietary quality index;[1]Kruskal-Wallis analysis [2]data obtained from 400 participants.

Table 4. Characteristics of the participants by diastolic BP values (the higher quartile *vs* lower quartiles)

	Diastolic BP>70 mmHg	Diastolic BP≤70 mmHg	P
Number	284	916	
Sodium from snacks (g/day)	1.6±0.6	1.3±0.5	<0.001
Frequency of salty snack consumption/day			
0-1	25.0	42.6	
>1-2	32.4	26.6	
>2	42.6	30.8	<0.001
Age (years)	12.1±0.5	12.1±0.5	0.14
Males (%)	51.1	51.4	0.91
Metabolic equivalent of activity[1] (METs h/week)	19.5 (26.0)	18.0 (32.0)	0.56
Weight (kg)	49.6±11.6	43.8±10.9	<0.001
Height (m)	1.52±0.07	1.49±0.09	0.002
BMI (kg/m^2)	21.5±4.2	19.4±3.8	<0.001
BMI percentile[1]	65 (57.0)	32.5 (56.0)	<0.001
BMI≥85thpercentile(%)	25.7	13.2	<0.001
Systolic BP (mmHg)	119.7±12.2	106.1±11.0	<0.001
Diastolic BP (mmHg)	76.6±5.6	61.9±5.6	<0.001
Pulse pressure (mmHg)	43.0±10.5	44.2±9.1	0.06
Total kcal[2]	2022.0±489.5	2008.1±428.3	0.79
Carbohydrates (% kcal)[2]	51.2±14.9	51.2±14.7	0.99
Fat (% kcal)[2]	35.9±10.3	35.8±10.2	0.88
SFA (% kcal)[2]	10.9±3.1	10.7±3.2	0.63
Protein (% kcal)[2]	12.9±3.9	13.0±3.9	0.70

Fiber (g/day) [2]	15.3±6.2	16.1±5.9	0.29
SDQI score[2]	71.6±14.7	74.2±14.2	0.12
Total sodium (g/day) [2]	3.2±0.8	2.6±0.9	0.01

Mean ±SD (all such values); median (inter-quartile range) (all such values); BMI=body mass index; BP=blood pressure; SFA= saturated fatty acids; SDQI= simple dietary quality index;[1]Kruskal-Wallis analysis [2]data obtained from 400 participants.

Table 5. Association of being in the highest systolic BP quartile (upper part) or being in the highest diastolic BP quartile (lower part) with sodium from snacks and frequency of salty snacks consumption in a multiple logistic regression model.

	Being in the highest systolic BP quartile		
	OR	**95%CI**	**P**
Age (years)	1.11	0.82-1.50	0.49
Males	0.88	0.65-1.18	0.39
Log-METs h/week	1.03	0.88-1.20	0.71
BMI (kg/m^2)	1.26	1.22-1.31	<0.001
Sodium from snacks (g/day)	1.48	1.14-1.91	0.003
	Being in the highest systolic BP quartile		
	OR	**95%CI**	**P**
Age (years)	1.10	0.81-1.48	0.54
Males	0.88	0.65-1.18	0.38
Log-METs h/week	1.04	0.89-1.22	0.59
BMI (kg/m^2)	1.26	1.22-1.31	<0.001
Frequency of consumption of salty snacks/day			
0-1	1		
>1-2	1.37	0.95-1.97	0.09
>2	1.86	1.32-2.63	<0.001
	Being in the highest diastolic BP quartile		
	OR	**95%CI**	**P**
Age (years)	1.08	0.81-1.46	0.59

Males	0.90	0.68-1.20	0.47
Log-METs h/week	1.15	0.99-1.34	0.07
BMI (kg/m^2)	1.14	1.10-1.18	<0.001
Sodium from snacks (g/day)	2.17	1.68-2.79	<0.001
	Being in the highest diastolic BP quartile		
	OR	**95%CI**	**P**
Age (years)	1.12	0.84-1.50	0.44
Males	0.91	0.69-1.22	0.54
Log-METs h/week	1.16	0.99-1.35	0.06
BMI (kg/m^2)	1.14	1.10-1.17	<0.001
Frequency of consumption of salty snacks/day			
0-1	1		
>1-2	2.09	1.47-3.00	<0.001
>2	2.38	1.69-3.37	<0.001

BMI= body mass index, BP= blood pressure, METs = Metabolic equivalent of activity