Nutrición Hospitalaria

Nutr Hosp. 2014;29(6):1283-1289
ISSN 0212-1611 • CODEN NUHOEQ
S.V.R. 318

Original / *Obesidad*

Sodium intake may promote weight gain; results of the FANPE study in a representative sample of the adult Spanish population

Beatriz Navia[1,2], Aránzazu Aparicio[1,2], José Miguel Perea[2,3], Napoleon Pérez-Farinós[4], Carmen Villar-Villalba[4], Estefania Labrado[4] and Rosa María Ortega[1,2]

[1]Departamento de Nutrición. Facultad de Farmacia. Universidad Complutense de Madrid. España. [2]UCM Research Group VALORNUT (920030). [3]Facultad de Ciencias de la Salud. Universidad Alfonso X El Sabio. Madrid. España. [4]Agencia Española de Consumo, Seguridad Alimentaria y Nutrición (AECOSAN). Ministerio de Sanidad, Servicios Sociales e Igualdad. España.

Abstract

Introduction: **Recent studies have indicated that diets rich in sodium may predispose to the development of obesity, either directly, or be associated with the consumption of foods that promote weight gain.**

Objetive: **The aims of this study were to analyze the association between urinary sodium and the presence of excess of weight. Additionally, the study investigated the relationships between salt intake and dietary habits, as a high salt intake may be associated with inadequate eating habits and a high incidence of obesity.**

Methods: **This study involved 418 adults (196 men and 222 women) aged 18 to 60 years old. Weight, height and waist circumference were measured, and we calculated, BMI and waist/height ratio. Dietary intake was estimated using a "24 h recalls", for two consecutive days, and sodium content was determined from 24 h urine sample.**

Results: **The 34.4% of the population had overweight and 13.6% had obesity. A positive association was seen between BMI and urinary sodium concentration. Urine sodium values were also positively associated with others adiposity indicators such as waist circumference and waist/height ratio. Body weight, BMI, waist circumference, and waist/height ratio were higher in the group of individuals with a urinary sodium excretion ≥ 154 mmol/l (Percentile 50) (P50). Additionally, individuals placed in this group presented a higher caloric intake and total food intake, in particular, more meat, processed food and snacks. Adjusting by energy intake, a higher sodium intake was a risk factor of being overweight or obese (OR = 1.0041, IC 95% 1.0015-1.0067, p < 0.01).**

Conclusions: **Salt intake was associated with obesity; since people with higher sodium intake consumed more energy and presented worse eating habits. Additionally, sodium intake itself appears to be related to obesity.**

(*Nutr Hosp.* 2014;29:1283-1289)

DOI:10.3305/nh.2014.29.6.7361

Key words: *Sodium. Obesity. Overweight. Adults.*

LA INGESTA DE SODIO PUEDE FAVORECER EL INCREMENTO DE PESO; RESULTADOS DEL ESTUDIO FANPE REALIZADO EN UNA MUESTRA REPRESENTATIVA DE ADULTOS ESPANOLES

Resumen

Introducción: **Estudios recientes, han señalado que las dietas ricas en sodio podrían predisponer a la aparición de obesidad, ya sea de forma directa, o por estar asociadas con el consumo de alimentos que favorecen el aumento de peso.**

Objetivo: **El objeto de este estudio fue analizar la asociación entre sodio urinario y presencia de sobrepeso y obesidad, en una muestra representativa de adultos españoles, así como conocer si el mayor consumo de sal, se asocia con unos peores hábitos alimentarios y con una mayor ingesta de alimentos, que puedan predisponer a la aparición de la misma.**

Métodos: **Se ha estudiado un grupo de 418 adultos (196 hombres y 222 mujeres) de 18 a 60 años de edad. Se recogieron datos de peso, talla, circunferencia de cintura y se calculó, a partir de ellos, el IMC y el índice cintura/talla. Con el fin de conocer el consumo de alimentos, se aplicó un "Recuerdo de 24 horas" durante dos días consecutivos y se determinó el sodio en orina de 24 horas.**

Resultados: **Un 34,4% de la población presentó sobrepeso y un 13,6% obesidad. Se observó una asociación positiva entre el IMC y la excreción urinaria de sodio. Los valores de sodio en orina también se relacionaron de forma directa con otros parámetros indicadores de adiposidad, como la circunferencia de la cintura o la relación cintura/talla. Tanto el peso, como el IMC, la circunferencia de la cintura y la relación cintura/talla, fueron mayores en el grupo con una excreción urinaria de sodio ≥ 154 mmol/l (Percentil 50) (P50). Además, las personas con una mayor eliminación urinaria de sodio presentaron una mayor ingesta calórica y un mayor consumo de alimentos totales y, en concreto, de carnes, precocinados y aperitivos. Tras ajustar por la ingesta de energía, la mayor ingesta de sodio resultó ser un factor de riesgo de tener un IMC más alto (OR = 1.0041, IC 95% 1.0015-1.0067, p < 0,01).**

Conclusiones: **La ingesta de sal estuvo asociada con la presencia de obesidad, ya que las personas con una mayor ingesta de sodio ingirieron más energía y presentaron peores hábitos alimentarios. Sin embargo, la ingesta de sodio por sí misma, también parece estar relacionada con el padecimiento de obesidad.**

(*Nutr Hosp.* 2014;29:1283-1289)

DOI:10.3305/nh.2014.29.6.7361

Palabras clave: *Sodio. Obesidad. Sobrepeso. Adultos.*

Correspondencia: Beatriz Navia Lombán.
Departamento de Nutrición.
Facultad de Farmacia.
Universidad Complutense de Madrid.
28040 Madrid.
E-mail: bnavialo@ucm.es

Recibido: 18-II-2014.
Aceptado: 12-III-2014.

Abreviaturas

IMC: Índice de masa corporal.
BMI: Body mass index.
WHO: World Health Organization.
NaE: Excreción urinaria de sodio; Urinary sodium excretion.
SD: Desviación estándar; Standard deviation.

Introduction

Obesity is considered as a mayor public health problem because of its high prevalence and the diseases associated to it, such as respiratory complications, cardiovascular disease, diabetes type 2, osteoarthritis, hypertension and some type of cancer[1].

Traditionally, obesity has been proposed as an energy imbalance; however, several authors have suggested that some environmental factors might alter the susceptibility of suffering it[2-5]. Recent studies have related salt intake and obesity that could increase the risk of suffering several diseases[6-8]. Although this possible association appears to be extremely complex[9,10], it could be possible that salt intake may promote the consumption of certain foods that facilitate weight gain[4]. Moreover, it could be possible that people with excess of weight make worse food choices, especially those foods with high contain of sodium and this situation could enhanced the higher sodium intake in weight gain and eating habits that promote weight gain with increased sodium intake. However, there are few studies that relate salt intake to overweight and obesity, or to food consumption.

Therefore, the aim of the present study was to determine the possible association between urinary sodium excretion (as a biomarker of salt intake) and presence of overweight and obesity in a representative sample of Spanish adults. The study also analyzed the relationship between salt intake and dietary habits and caloric intake.

Methods

Study subjects

The cross-sectional study included 196 men and 222 women (total 418) aged 18-60 years (36.4 ± 11.8), selected as a representative sample of the Spanish young and middle-aged adult population. All data were collected between January and September 2009.

The simple size was planned, taking into account data provided by the Spanish Intersalt Study[11], to be representative for each sex, assuming a dropout rate of 25%. The initial sample size required was set at 406 participants. Sampling was performed in fifteen randomly selected provinces (selected with the proviso that the great majority of Spain's autonomous regions be included), including the capital city of each province and a semi-urban/rural city (randomly chosen). The total number of sampling points was therefore 30. In each sampling point, participants were divided into six subgroups, taking into account their sex (male/female) and age (18-30, 31-44 and 45-60 years).

Individuals with a diagnosis of diabetes mellitus, hypertension or renal disease, or who had been prescribed diuretics, were excluded. All select participants were healthy and lived in their own homes; neither hospitalised people nor those living in institutions were included in the present study.

Participants were randomly selected among the residents of each population and were invited to take part in the study via telephone (or in person in some of the rural areas). When a participant was excluded at any site, or when participation was declined, another person of the same sex and age group was contacted. Of the 1,835 people spoken to, 492 (26.8%) accepted the invitation to be included in the study. Of these, seventy-four were excluded. The final study sample therefore consisted of 418 participants (53.6% women; 22.8% of the original contacted sample).

The present study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures were approved by the Human Research Review Committee of the Pharmacy Faculty (Complutense University of Madrid, Spain). Written informed consent was obtained from all subjects.

Health variables

Information was collected from all participants on health problems, and on the consumption of medications (data required to determine whether the participants met the inclusion criteria), supplements and manufactured dietary foods.

Anthropometric survey

All date were collected following norms set out by the WHO[12]. Weight and height were determined using a digital electronic balance (Seca Alpha, GmbH & Co., Igni, France; range 0.1-150 kg, precision 100 g) and a Harpender digital stadiometer (Pfifter, Carlstadt, NJ, USA; range 70-205 cm, precision 1 mm), respectively. For both measurements, participants were barefoot and wore only underwear. The body mass index (BMI; kg/m^2) was then calculated.

Waist circumference was determined using a tape (Holtain Ltd., Dyfed, UK; range 0-150 cm, precision 1 mm). This measurement was made with the person stood comfortably with his/her weight evenly distributed on both feet. The measurement was taken midway between the inferior margin of the last rib and the crest of the ileum in a horizontal plane. For the hip measurement the subjects stood erect with the arms at the sides and feet together. The measurement sat at the side of the subject so that the level of maximum extension of the buttocks could be seen, and placed the tape measure around the buttocks in a horizontal plane. In both cases, the tape did not compress the soft tissues. The waist/height ratio was then calculated.

Dietary survey

A "24 h recall" questionnaire was used to register all intakes for two consecutive days[13]. Each of the subjects was asked about their consumption of food and drinks at each main meal or between meals, as well as the trademark or the type of food and the portion sizes consumed. Subjects were instructed to record the weights consumed if possible, and household measurements (spoonfuls, cups, etc) if not. They should also indicate the portion size consumed (small, medium or large) and if the foods listed were taken raw or cooked, with or without bone, with or without skin, etc.

The energy and nutrient contents of the ingested foods were then calculated using the Food Composition Tables of the Department of Nutrition, Complutense University of Madrid[14]. DIAL software (Alce Ingenieria) was used to process all data[15].

Theorical energy expenditure was established using equations proposed by the WHO (1985), multiplied by the activity ratio[16,17]. To validate de results of the dietetic study energy intake was compared to the theoretical expenditure. The percentage of discrepancy between energy expenditure and the sum the measured and declared intake was determined using the following formula: (theoretical energy expenditure-energy intake) × 100/ theoretical energy expenditure[16,18].

A negative value indicates the component involving the declared energy intake to be greater than that of the theoretical energy expenditure (probable over-reporting), while a positive value indicates it to be lower than that of the theoretical energy expenditure (probable under-reporting)[16,18].

Physical activity

Participants completed a questionnaire on their usual physical activity[17]. This information was used to calculate estimated energy expenditure. Participants indicated the length of time spent sleeping, eating, playing sports, etc. during working days and weekends. An activity coefficient was established for each participant by multiplying the time spent in each activity by established coefficients[16,17] –1 for sleeping and resting, 1.5 for very light activities (those that can be done sitting or standing up such as ironing, typing or painting), 2.5 for light activities (e.g. walking), 5 for moderate activities (e.g. playing tennis, skiing and dancing) and 7 for intensive activities (e.g. cutting down trees and playing basketball) – and then dividing them by 24 h.

This data provided two coefficients, one for weekdays and one for weekends. The weekday coefficient was multiplied by 6, the coefficient for Sunday was then added to this and the total was divided by 7. This provided a final activity coefficient for each participant, which was multiplied by the baseline expenditure[16,17] to provide the theoretical energy expenditure for each participant.

Urine testing

Urinary sodium excretion (NaE) was quantified using an indirect potentiometer with selective solid membranes for this ion, connected to an Olympus AU 5400 autoanalyser (Mishima, Japan)[19] (CV = 1.0%). Percentile 50 of 24 h NaE were calculated: NaE (mmol/L) P50 = 154 nmol/L.

The details about the interviews and the phases in the application of questionnaires and methods have been published previously[20].

Statistical analysis

Means and standard deviations were calculated for all variables (Mean ± SD) and the normality of the data was checked. To analyze the intergroup differences was applied Student's t test (or the Mann–Whitney test if the distribution of results was not homogeneous). To eliminate the influence of some variable such as sex and age, we used analysis of covariance (ANCOVA). To establish the association between two variables Pearson's correlation was used. Relationships between variables were examined by multiple linear regressions, controlling for potential confounders (sex, age, etc.). To compare qualitative variables X^2 test was used. Comparisons between proportions were made using an approximation of the binomial distribution to the normal distribution, employing continuity correction.

All calculations were executed using RSIGMA BABEL Software (Horus Hardward, Madrid, Spain). The significance was set at $p < 0.05$.

Results

The individual characteristics (personal, anthropometric, sanitary data and urinary sodium concentration) are shown in table I. The weight, height, BMI, waist circumference and waist/height ratio were significantly higher in men than in women, as well as the values of urinary sodium concentration values. The 34.4% of the participants were classified as overweight and 13.6% as obese, with a higher percentage of overweight men than women ($p < 0.001$). No differences were found between the activity coefficient of males and females.

Table I
Personal, anthropometric and sanitary characteristics of the study population according to sex (Mean ± SD)

	Total	*Men*	*Women*
n	418	196	222
Age (years)	36.4 ± 11.8	36.2 ± 11.7	36.6 ± 11.9
Weight (kg)	71.8 ± 14.8	81.2 ± 13.1***	63.6 ± 10.9***
Height (cm)	168.0 ± 9.9	175.6 ± 7.4***	161.4 ± 6.6***
BMI (kg/m^2)	25.3 ± 4.1	26.4 ± 4.1***	24.4 ± 4.0***
Overweight (%)	34.4	44.4***	25.7***
Obese (%)	13.6	16.3	11.3
Waist circumference (cm)	85.9 ± 13.3	92.4 ± 11.7***	80.2 ± 12.0***
Waist/Height ratio	0.51 ± 0.08	0.53 ± 0.07***	0.50 ± 0.08***
Physical activity coefficient	1.62 ± 0.18	1.62 ± 0.16	1.63 ± 0.19
NaE 24 h (mmol/L)	168.0 ± 78.6	196.3 ± 81.8***	142.9 ± 66.4***

NaE: urinary sodium excretion.
*p < 0.05; **p < 0.01;***p < 0.001.

According to the NaE (≥P50 NaE (154 mmol/L) or < P50 NaE), and after controlling for sex, those subjects in the NaE ≥ P50 group had higher weight, BMI, waist circumference and waist/height ratio values, and a higher percentage of obese, (table II) than those in the NaE < P50 group. A positive association was seen between BMI and urinary sodium excretion ($\beta = 0.0082 \pm 0.0024$; $p < 0.001$) ($R^2 = 0.2799$; $p < 0.001$) (data adjusted by sex and age). Likewise, after controlling for sex and age, urinary sodium values also correlated with other anthropometric indicators of adiposity such as waist circumference ($\beta = 1.11 \pm 0.34$; $p < 0.001$) ($R^2 = 0.3696$, $p < 0.001$) and the waist/height ratio ($\beta = 137.4 \pm 57.4$; $p < 0.05$) ($R^2 = 0.1267$, $p < 0.001$).

Those subjects in the NaE ≥P50 group had a higher energy intakes ($p < 0.001$) and ingested a higher amount of food ($p < 0.05$) than those in the NaE < P50 group. Additionally, meat ($p < 0.05$), processed food ($p < 0.05$) and snacks ($p < 0.05$) intake was higher in the individuals placed in the NaE ≥ P50 group (table III). Beverages consumption also was significantly higher ($p < 0.01$) in those persons with higher urinary sodium excretion (NaE ≥ P50). High sodium intake was also associated with higher BMI (OR=1.0041, IC 95% 1.0015-1.0067, $p < 0.01$) (data adjusted by energy intake), keeping the differences in the food consumption mentioned above.

Discussion

The percentages of overweight and obesity found in this study (34.4% and 13.6% respectively) were lower than compared with the percentages observed in USA (66.3% and 32.2%), UK (61.0% and 22.7%), Australia (49.0% and 16.4%) and Canada (48.2% and 14.9%). However, these percentages were higher than those observed in Japan (23.2% and 3.10%), China (18.9% and 2.9%) and Indonesia (13.4 and 2.4%)[21].

The measurement of 24 h urinary sodium excretion is considered the 'gold standard' method for measuring so-

Table II
Personal, anthropometric and sanitary characteristics of the study population according to urinary sodium excretion (NaE) (Mean ± SD)

	< P50 NaE	*≥ P50 NaE*
n	205	210
Men (%)	30.7***	62.9***
Women (%)	69.3***	37.1***
Age (years)	36.7 ± 12.2	36.2 ± 11.5
Weight (kg)	67.0 ± 13.1***	76.5 ± 15.0***
Height (cm)	165.0 ± 9.0*	170.9 ± 10.0*
BMI (kg/m^2)	24.5 ± 3.8**	26.1 ± 4.3**
Overweight (%)	32.7	35.7
Obese (%)	8.8**	18.6**
Waist circumference (cm)	82.6 ± 12.5 NP	89.1 ± 13.3 NP
Waist/Height ratio	0.50 ± 0.07 NP	0.52 ± 0.08 NP
Physical activity coefficient	1.62 ± 0.19	1.63 ± 0.17
NaE 24 h (mmol/L)	105.3 ± 31.6***	229.2 ± 60.5***

NaE: urinary sodium excretion
*p < 0.05; **p < 0.01;***p < 0.001, NP: not parallel. Data adjusted by sex.

Table III
Dietary data and food consumption according to urinary sodium excretion (NaE) (Mean ± SD)

	< P50 NaE	*≥ P50 NaE*
Energy (kJ/day)	10103 ± 1812***	11547 ± 2014***
Under-reporting (kJ/day)	1483 ± 2858	1907 ± 2798
Under-reporting (%)	13.1 ± 27.9	15.4 ± 22.8
Food consumption (g/day)	2180 ± 730.8*	2447 ± 911.9*[a]
Cereals	162.4 ± 80.3	183.5 ± 92.3
Legumes	22.3 ± 51.1	24.1 ± 51.1
Vegetables	274.0 ± 169.6	297.4 ± 163.9
Fruits	264.8 ± 232.3	248.6 ± 216.1
Dairy products	366.4 ± 228.7	352.8 ± 170.8
Meats	143.6 ± 93.5*	181.5 ± 119.6*[a]
Fish	84.4 ± 88.1	91.8 ± 101.6
Eggs	26.8 ± 31.9	28.7 ± 28.8
Sugars	22.6 ± 35.8	22.5 ± 34.8
Fats and oils	34.1 ± 17.3	36.4 ± 15.3
Beverages	748.6 ± 583.2**	930.0 ± 765.1**[a]
Precooked	15.4 ± 44.9*	30.2 ± 87.0*[a]
Snacks	5.8 ± 14.1*	9.8 ± 20.1*[a]
Sauces	9.8 ± 12.3	10.0 ± 12.0
Others	0.42 ± 4.10	0.09 ± 1.04

*p < 0.05; **p < 0.01;***p < 0.001. Data adjusted by sex.
a Significant differences between groups adjusting for energy intake and sex.

dium intakes in population surveys because of the problems of underestimation of sodium intakes based on dietary surveys in most studies[22-24]. The mean 24 h urinary sodium excretion recorded in the present study was similar to that recorded by other authors in similar groups both Spanish11 and other countries[25,26]. Interestingly urinary sodium concentrations were higher in males than in females (table I). Similarly, high urinary sodium excretion has been observed in men have been reported by other authors, probably due to a higher food intake by the male individuals compared to female[7,24,25], characteristic that was also observed in the present study (male food intake: 2493.0 ± 912.2 g/day *vs* female food intake: 2153.3 ± 730 g/day, $p < 0.001$). In consequence, the male individuals had a higher sodium intake.

Several studies have found no association between urinary sodium excretion and different anthropometric indexes of adiposity. However, the results of the Olivetti Heart Study$_8$ showed that urinary sodium excretion was significantly higher in participants with overweight or obesity than those with normal weight. Accordingly, in the present study, and after adjusting by sex, it was observed that individuals with BMI values indicative of obesity had a higher urinary sodium excretion (205.8 ± 84.5 mmol/L) than those classified as overweight (169.5 ± 78.5 mmol/L) and normoweight (157.0 ± 74.2 mmol/L). It was also found that urinary sodium excretion was a predictor factor of BMI. Specifically, the amount of sodium excreted in urine was about 30% higher in obese people than in normoweight individuals. Assuming that the urinary sodium excretion comes from the diet (168.0 ± 78.6 mmol/day), this excretion would correspond to a mean salt intake of 9.8 ± 4.6 g/day in the total population and 9.2 ± 4.3, 9.9 ± 4.6 and 12.0 ± 4.9 g/day in people with normoweight, overweight and obese individuals ($p < 0.01$, data adjusted for sex). This means that 82.5% of normoweight subjects, 87.6% overweight and 100% of obese had sodium intakes above 5 g/day (maximum recommended)[27].

It was also observed a positive association between urinary sodium excretion values and waist circumference or waist/height ratio, which is in agreement with those obtained by Hoffman and Cubeddu[7], who in a sample of 766 adults found an association between several parameters related to obesity, such as body weight, BMI and waist circumference, with urinary sodium excretion values. Moreover, our results agrees with the findings of Venezia et al.[8], who observed that the urinary sodium excretion was positively related with BMI and with the arm circumference, the waist circumference. This correlation was not observed with the triceps and subscapular skinfolds.

In our study, those subjects with a NaE ≥ P50 had higher weight, BMI, waist circumference and the waist/height ratio values and a higher percentage of obese (table II) than those with a NaE < P50. No significant differences were seen in physical activity coefficient between groups (table II). This results are in agreement with the findings of Hu et al.[28], who in their study performed in Finland, reported that people in the largest quintile of urinary sodium excretion were more obese, more hypertensive, and had a higher risk of diabetes type 2 than those in the lower quintiles.

Interestingly, it has been suggested that a high sodium intake is associated with obesity and several hypotheses have been stated. In several animal studies, the intake of monosodium glutamate (glutamic acid sodium salt, commonly used as an additive) has been related to overweight and obesity. Monosodium glutamate can alter the mechanisms regulating fat metabolism, leading to the appearance of this pathology[29]. In fact, in a study by He et al.[9] in a group of 752 Chinese subjects (40-59 years) revealed that, after adjust by physical activity and energy intake, monosodium glutamate intake was positively associated with BMI. These results may point salt intake as the possible cause of obesity.

Another hypothesis proposed to explain the relationship between sodium intake and obesity is one that indicates that salty foods could be considered addictive substances which stimulate opioid receptors in the brain and the pleasure center. Moreover, this theory also suggests that when these receptors are not stimulated increases preference, desire or appetite for salty foods. Furthermore, it also proposes that the consumption of salty foods every day produces an addiction to these foods, producing an increase in food consumption (tolerance to opiates), increased caloric intake, overweight, lifestyle sedentary, obesity and related diseases[10]. Therefore, obesity would not be caused by salt intake itself, but by the predisposition that high salt intake generates, promoting the ingestion of less healthy and more palatable foods, and increasing energy intake, which possibly will increase body weight[10]. In addition, several studies that indicate that low sodium diets are considered as unpalatable[30], reducing food intake. Some studies have indicated that that low sodium diets in rats increased plasma angiotensin II concentrations[31,32], peptide that has the ability of reduce food intake when administered systemically and intra-cerebroventricular[33,34].

In this respect, in our study, we observed that those subjects in the NaE ≥ P50 group had higher energy intakes than those in the Na E < P50 group (table III), but no significant differences in the physical activity coefficient between groups were seen (table II).

The relationship between salt intake and beverages consumption has been widely reported in both observational epidemiological studies and clinical trials[35,36], where diets high in sodium were associated with fluid intakes[37,38]. In fact, it has been estimated that reducing salt intake from 10 g/day to 5 g/day (maximum recommended)[27] could reduce fluid intake by 350 mL/day[36]. In the present study, water intake was significantly higher in subjects in the NaE ≥ P50 group (1,849 ± 810.1 mL/day) than in those in the NaE < P50 group (1643 ± 653.5 mL/day) ($p < 0.01$). However, after adjusting by sex, it was seen that these differences were caused by the increase water intake observed in male participants (males: 1869 ± 816.2 mL/day; females: 1629 ± 655.0 mL/day; $p < 0.01$). In contrast, those individuals in the NaE ≥ P50 group consumed greater amount of beverages (table III), group that includes beverages other than water, such as soda, commercial fruit juices, and alcoholic drinks[14]. This high intake of beverages other than water has been widely reported[4,9,36] and may also contribute to the increase of body weight.

The higher food consumption observed in the group of people with higher salt intakes (≥ P50) ingested more snacks and more processed food, which normally have a high salt and calorie contain[14]. Therefore, it was not strange to place these individuals in the high sodium excretion group and found more obese individuals within this group.

Moreover, several studies have found association between meat consumption and different measures of adiposity in adults, such as BMI and waist circumference and the presence of obesity and central obesity and might be associated with the high calorie contain of meat[39]. Similarly, the present study shoed a positive relationship between urinary sodium excretion and waist circumference, BMI and percentage of obese individuals ($\beta = 0.0179 \pm 0.077$, $p < 0.05$), data adjusted by sex, age, under-reporting of energy intake and weight ($R^2 = 0.2153$, $p < 0.001$). In addition, an inverse association between meat and fruit consumption was observed ($r = -0.1187$, $p < 0.05$). Previous studies have observed how high meat intakes could displace vegetable and fruit consumption, increasing the chances of following a caloric unbalanced diet[40].

In the present study, salt intake was associated with the presence of obesity, possibly because people with higher sodium intake have a higher caloric intake, food consumption and worse eating habits (eating more meat, snacks and others), and this association remained after adjusting for energy intake. It is possible therefore that people with a higher intake of salt to eat more, to make it the food more palatable and desirable and also that eating foods high in salt, being in turn, higher-calorie foods, especially processed, favors the development of obesity, but regardless of energy intake, the results obtained in this study suggest that taking more sodium, predisposes to obesity.

In this sense, it is necessary to design public health policies to reduce the sodium consumption and to improve their eating habits. These might include to engaging with the food industry to reduce the large amount of salt commonly included in processed foods. All this initiatives would have a positive effect on population health.

Acknowledgments

The present study was supported by the AECOSAN (Spanish Agency of Consumers Affairs, Food Safety and Nutrition, Spanish Ministry of Health, Social Services and Equality, Spain) (Project 337/2008).

References

1. World Health Organization. Obesity: Preventing and managing the global epidemic. Technical Report Series. Vol. 894. WHO: Geneva, Switzerland, 2000. pp. 1-253.

2. Cournot M, Ruidavets JB, Marquié JC, Esquirol Y, Baracat B, Ferrières J. Environmental factors associated with body mass index in a population of Southern France. *Eur J Cardiovasc Prev Rehabil* 2004; 11 (4): 291-7.
3. Malik VS, Schulze MB, Hu FB. Intake of sugar-sweetened beverages and weight gain: a systematic review. *Am J Clin Nutr* 2006; 84 (2): 274-88.
4. He FJ, Marrero NM, MacGregor GA. Salt intake is related to soft drink consumption in children and adolescents: a link to obesity? *Hypertension* 2008; 51 (3): 629-34.
5. Vgontzas AN, Lin HM, Papaliaga M et al. Short sleep duration and obesity: the role of emotional stress and sleep disturbances. *Int J Obes (Lond)* 2008; 32 (5): 801-9.
6. Taylor EN, Curhan GC. Body size and 24-hour urine composition. *Am J Kidney Dis* 2006; 48 (6): 905-15.
7. Hoffmann IS, Cubeddu LX. Salt and the metabolic syndrome. *Nutr Metab Cardiovasc Dis* 2009; 19 (2): 123-8.
8. Venezia A, Barba G, Russo O et al. Dietary sodium intake in a sample of adult male population in southern Italy: results of the Olivetti Heart Study. *Eur J Clin Nutr* 2010; 64 (5): 518-24.
9. He K, Zhao L, Daviglus ML et al. INTERMAP Cooperative Research Group. Association of monosodium glutamate intake with overweight in Chinese adults: the INTERMAP Study. *Obesity (Silver Spring)* 2008; 6 (8): 1875-80.
10. Cocores JA, Gold MS. The Salted Food Addiction Hypothesis may explain overeating and the obesity epidemic. *Med Hypotheses* 2009; 73 (6): 892-9.
11. Intersalt Cooperative Research Group. Intersalt: an international study of electrolyte excretion and blood pressure. Results for 24 hour urinary sodium and potassium excretion. *Br Med J* 1988; 297: 319-28.
12. World Health Organization. Methology of Nutritional Surveillance. Physical Condition: Use and Interpretation of Anthropometric Data. Joint FAO/UNICEF/WHO Expert Consultation. Technical Report Series nº. 854. WHO: Geneva, 1995.
13. Ortega RM, Povea FI. Dietetic study. In: Requejo AM, Ortega RM (eds) Nutriguía. Manual of Clinical Nutrition in Primary Care. Editorial Complutense: Madrid, 2006. pp. 335-45.
14. Ortega RM, López-Sobaler AM, Requejo AM, Andrés P. Food composition. A basic tool for assessing nutritonal status. Editorial Complutense: Madrid, 2010.
15. Ortega RM, López-Sobaler AM, Andrés P, Requejo AM, Aparicio A, Molinero LM: Programa DIAL para valoración de dietas y cálculos de alimentación. Departamento de Nutrición (UCM) y Alce Ingeniería, S.A. Madrid; 2004. http: //www.alceingenieria.net/ nutricion.htm. [Accessed 2010 December].
16. World Health Organization. Energy and protein requirements. Report of a joint FAO/WHO/ONU expert consultation. Technical report series 724. World Health Organization: Geneva, 1985, pp 71-80.
17. Ortega RM, Requejo AM, López-Sobaler AM. Activity questionnaire. In: Requejo AM, Ortega RM (eds). Nutriguía. Manual of Clinical nutrition in Primary Care. Editorial Complutense: Madrid, 2006. pp. 468.
18. Ortega RM, Requejo AM, Quintas ME, Sánchez-Quiles B, López-Sobaler AM, Andrés P. Estimated energy balance in female university students: differences with respect to body mass index and concern about body weight. *Int J Obes Relat Metab Disord* 1996; 20 (12): 1127-9.
19. Ng RH, Altaffer M, Ito R, Statland BE. The Technicon RA-1000 evaluated for measuring sodium, potassium, chloride, and carbon dioxide. *Clin Chem* 1985; 31: 435-8.
20. Ortega RM, López-Sobaler AM, Ballesteros JM et al. Estimation of salt intake by 24 h urinary sodium excretion in a representative sample of Spanish adults. *Br J Nutr* 2011; 105: 787-94.
21. Low S, Chin MC, Deurenberg-Yap M. Review on Epidemic of Obesity. *Ann Acad Med Singapore* 2009; 38 (1): 57-9.
22. Institute of Medicine. Dietary Reference Intakes: water, potassium, sodium chloride, and sulphate. 1st ed. Washington DC: National Academy Press, 2004.
23. Cummins RO, Shaper AG, Walker M. Metodological problems with estimation salt intake. *Lancet* 1983; 5: 135-9.
24. Brown IJ, Tzoulaki I, Candeias V, Elliott P. Salt intakes around the world: implications for public health. *Int J Epidemiol* 2009; 38 (3): 791-813.
25. Laatikainen T, Pietinen P, Valsta L, Sundvall J, Reinivuo H, Tuomilehto J. Sodium in the Finnish diet: 20-year trends in urinary sodium excretion among the adult population. *Eur J Clin Nutr* 2006; 60 (8): 965-70.
26. Taylor EN, Curhan GC. Body size and 24-hour urine composition. *Am J Kidney Dis* 2006; 48 (6): 905-15.
27. World Health Organization. Diet, Nutrition and the Prevention of Chronic Diseases. Joint WHO/FAO Expert Consulation. WHO Thecnical Report Series nº 916. WHO: Geneva, 2003.
28. Hu G, Jousilahti P, Peltonen M, Lindström J, Tuomilehto J. Urinary sodium and potassium excretion and the risk of type 2 diabetes: a prospective study in Finland. *Diabetología* 2005; 48 (8): 1477-83.
29. Hermanussen M, Tresguerres JA. Does high glutamate intake cause obesity? *J Pediatr Endocrinol Metab* 2003; 16: 965-8.
30. Fonseca-Alaniz MH, Brito LC, Borges-Silva CN, Takada J, Andreotti S, Lima FB. High Dietary Sodium Intake Increase White Adipose Tissue Mass and Plasma Leptin in Rats. *Obesity* 2007; 15 (9): 2200-8.
31. Coelho MS, Passadore MD, Gasparetti AL et al. High- or low-salt diet from weaning to adulthood: effect on body weight, food intake and energy balance in rats. *Nutr Metab Cardiovasc Dis* 2006; 16: 148-55.
32. Ingert C, Grima M, Coquard C, Barthelmebs M, Imbs J. Effects of dietary salt changes on renal-angiotensin system in rats. *Am J Physiol Renal Physiol* 2002; 283: 995-1002.
33. English V, Cassis L. Facilitation of sympathetic neurotransmission contributes to angiotensin regulation of body weight. *J Neural Transm* 1999; 106: 631-44.
34. Porter JP, Potratz KR. Effect of intracerebroventricular angiotensin II on body weight and food intake in adult rats. *Am J Physiol Regul Integr Comp Physiol* 2004; 287: R422-R428.
35. He FJ, Markandu ND, Sagnella GA, McGregor GA. Effect of salt intake on renal excretion of water in humans. *Hypertension* 2001; 38: 317-20.
36. Karppanen H, Mevaala E. Sodium intake and hypertension. *Prog Cardiovasc Dis* 2006; 49: 59-75.
37. Okamoto MM, Sumida DH, Carvalho CR et al. Changes in dietary sodium consumption modulate GLUT4 gene expression and early steps of insulin signaling. *Am J Physiol Regul Integr Comp Physiol* 2004; 286: R779-R785.
38. Stricker EM, Hoffmann ML, Riccardi CJ, Smith JC. Increased water intake by rats maintained on high NaCl diet: analysis of ingestive behavior. *Physiol Behav* 2003; 79: 621-31.
39. Wang Y, Beydoun MA, Caballero B, Gary TL, Lawrence R. Trends and correlates in meat consumption patterns in the US adult population. *Public Health Nutr* 2010; 13 (9): 1333-45.
40. Leitzmann C. Vegetarian diets: what are the advantages? *Forum Nutr* 2005. pp. 147-56.