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

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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.

Objective: The aims of this study were to analyze the associations 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 weight/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.

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Key words: Sodium. Obesity. Overweight. Adults.

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 ingerirían más energía y presentarían peores hábitos alimentarios. Sin embargo, la ingesta de sodio por sí misma, también parece estar relacionada con el padecimiento de obesidad.

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participants. Sampling was performed in fifteen ran-
25%. The initial sample size required was set at 406
representative for each sex, assuming a dropout rate of

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 prob-
problem because of its high prevalence and the diseases
associated to it, such as respiratory complications, car-
diovascular disease, diabetes type 2, osteoarthritis, hy-
pertension and some type of cancer1.

Traditionally, obesity has been proposed as an
energy imbalance; however, several authors have sug-
gested that some environmental factors might alter the
susceptibility of suffering it2-5. Recent studies have re-
lated salt intake and obesity that could increase the risk
of suffering several diseases6-8. Although this possible
association appears to be extremely complex9,10, it
could be possible that salt intake may promote the con-
sumption of certain foods that facilitate weight gain1.
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 stu-
dies that relate salt intake to overweight and obesity, or
to food consumption.

Therefore, the aim of the present study was to deter-
mine 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 relation-
ship 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), se-
lected as a representative sample of the Spanish young
and middle-aged adult population. All data were col-
clected between January and September 2009.

The simple size was planned, taking into account da-
ta provided by the Spanish Intersalt Study11, to be re-
presentative for each sex, assuming a dropout rate of
25%. The initial sample size required was set at 406
participants. Sampling was performed in fifteen ran-
domly selected provinces (selected with the proviso
that the great majority of Spain’s autonomous regions
be included), including the capital city of each provin-
ce 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 prescri-
bded diuretics, were excluded. All select participants
were healthy and lived in their own homes; neither hos-
pitalised people nor those living in institutions were in-
cluded in the present study.

Participants were randomly selected among the resi-
dents 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 si-
te, 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 invi-
tation 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 (Complu-
tense 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 medica-
tions (data required to determine whether the partici-
pants met the inclusion criteria), supplements and ma-
ufactured dietary foods.

Anthropometric survey

All data were collected following norms set out by
the WHO12. Weight and height were determined using
a digital electronic balance (Seca Alpha, GmbH & Co.,
Igini, France; range 0.1-150 kg, precision 100 g) and a
Harpender digital stadiometer (Pfiffter, 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/m²) 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 sto-
ded comfortably with his/her weight evenly distributed
on both feet. The measurement was taken midway be-
 tween the inferior margin of the last rib and the crest of
 the ileum in a horizontal plane. For the hip measure-
ment 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 days13. 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 Madrid14. DIAL software (Alce Ingenieria) was used to process all data15.

Theoretical energy expenditure was established using equations proposed by the WHO (1985), multiplied by the activity ratio16,17. To validate the results of the dietary 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: \( \frac{\text{theoretical energy expenditure-energy intake}}{\text{theoretical energy expenditure}} \times 100 \) = 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 under-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 activity15. 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 coefficients16,17 – 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 expenditure16,17 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 previously20.

**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 X2 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 R SIGMA BASEL 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.
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 (β = 0.0082 ± 0.0024; p < 0.001) (R² = 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 (β = 1.11 ± 0.34; p < 0.001) (R² = 0.3696, p < 0.001) and the waist/height ratio (β = 137.4 ± 57.4; p < 0.05) (R² = 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.

### Table I

<table>
<thead>
<tr>
<th></th>
<th>Total</th>
<th>Men</th>
<th>Women</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>418</td>
<td>196</td>
<td>222</td>
</tr>
<tr>
<td>Age (years)</td>
<td>36.4 ± 11.8</td>
<td>36.2 ± 11.7</td>
<td>36.6 ± 11.9</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>71.8 ± 14.8</td>
<td>81.2 ± 13.1***</td>
<td>63.6 ± 10.9***</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>168.0 ± 9.9</td>
<td>175.6 ± 7.4***</td>
<td>161.4 ± 6.6***</td>
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<tr>
<td>BMI (kg/m²)</td>
<td>25.3 ± 4.1</td>
<td>26.4 ± 4.1***</td>
<td>24.4 ± 4.0***</td>
</tr>
<tr>
<td>Overweight (%)</td>
<td>34.4</td>
<td>44.4***</td>
<td>25.7***</td>
</tr>
<tr>
<td>Obese (%)</td>
<td>13.6</td>
<td>16.3</td>
<td>11.3</td>
</tr>
<tr>
<td>Waist circumference (cm)</td>
<td>85.9 ± 13.3</td>
<td>92.4 ± 11.7***</td>
<td>80.2 ± 12.0***</td>
</tr>
<tr>
<td>Waist/Height ratio</td>
<td>0.51 ± 0.08</td>
<td>0.53 ± 0.07***</td>
<td>0.50 ± 0.08***</td>
</tr>
<tr>
<td>Physical activity coefficient</td>
<td>1.62 ± 0.18</td>
<td>1.62 ± 0.16</td>
<td>1.63 ± 0.19</td>
</tr>
<tr>
<td>NaE 24 h (mmol/L)</td>
<td>168.0 ± 78.6</td>
<td>196.3 ± 81.8***</td>
<td>142.9 ± 66.4***</td>
</tr>
</tbody>
</table>

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

### Table II

<table>
<thead>
<tr>
<th></th>
<th>&lt; P50 NaE</th>
<th>≥ P50 NaE</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>205</td>
<td>210</td>
</tr>
<tr>
<td>Men (%)</td>
<td>30.7***</td>
<td>62.9***</td>
</tr>
<tr>
<td>Women (%)</td>
<td>69.3***</td>
<td>37.1***</td>
</tr>
<tr>
<td>Age (years)</td>
<td>36.7 ± 12.2</td>
<td>36.2 ± 11.5</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>67.0 ± 13.1***</td>
<td>76.5 ± 15.0***</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>165.0 ± 9.0*</td>
<td>170.9 ± 10.0*</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>24.5 ± 3.8**</td>
<td>26.1 ± 4.3**</td>
</tr>
<tr>
<td>Overweight (%)</td>
<td>32.7</td>
<td>35.7</td>
</tr>
<tr>
<td>Obese (%)</td>
<td>8.8**</td>
<td>18.6**</td>
</tr>
<tr>
<td>Waist circumference (cm)</td>
<td>82.6 ± 12.5 NP</td>
<td>89.1 ± 13.3 NP</td>
</tr>
<tr>
<td>Waist/Height ratio</td>
<td>0.50 ± 0.07 NP</td>
<td>0.52 ± 0.08 NP</td>
</tr>
<tr>
<td>Physical activity coefficient</td>
<td>1.62 ± 0.19</td>
<td>1.63 ± 0.17</td>
</tr>
<tr>
<td>NaE 24 h (mmol/L)</td>
<td>105.3 ± 31.6***</td>
<td>229.2 ± 60.5***</td>
</tr>
</tbody>
</table>

NaE: urinary sodium excretion
*p < 0.05; **p < 0.01; ***p < 0.001, NP: not parallel. Data adjusted by sex.
Sodium intake may promote weight gain; results of the FANPE study in a representative sample of the adult...
potheses 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. In fact, in a study by He et al. in a group of 752 Chinese subjects (40-59 years) revealed that, after adjusting 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.

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. In addition, several studies that indicate that low sodium diets are considered as unpalatable, reducing food intake. Some studies have indicated that low sodium diets in rats increased plasma angiotensin II concentrations, peptide that has the ability of reduce food intake when administered systemically and intra-cerebroventricular.

In this respect, in our study, we observed that those subjects in the NaE ≥ P50 group had higher energy intakes than those in the NaE < 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, where diets high in sodium were associated with fluid intakes. In fact, it has been estimated that reducing salt intake from 10 g/day to 5 g/day (maximum recommended) could reduce fluid intake by 350 mL/day. 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 (1,643 ± 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. This high intake of beverages other than water has been widely reported 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. 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. Similarly, the present study showed a positive relationship between urinary sodium excretion and waist circumference, BMI and percentage of obese individuals (β = 0.0179 ± 0.077, p < 0.05), data adjusted by sex, age, under-reporting of energy intake and weight (R² = 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.

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

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References


