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ORIGINAL ARTICLE

Dietary sodium intake in a sample of adult male population in southern Italy: results of the Olivetti Heart Study

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Background/Objectives: To assess dietary habitual sodium intake and the association between daily sodium intake and anthropometric indices, food habits and hypertension in the sample of adult male population participating in the Olivetti Heart Study.
Subjects/Methods: The study population was composed of 940 men participating in the 2002–2004 follow-up examination of the Olivetti Heart Study. Blood pressure, anthropometric indices, biochemical parameters and sodium excretion in a 24-h urine collection were measured. The frequency of consumption of selected foods was estimated by a food frequency questionnaire (FFQ) capturing the previous year data. In a subgroup of the study population ($n = 138$), the fractional excretion of sodium was estimated by endogenous lithium clearance.
Results: Dietary sodium intake estimated by 24 h urinary excretion was 203 ± 70 mmol/day. Sodium excretion was significantly lower in treated hypertensive patients and higher in overweight/obese participants when compared with normotensive and normal-weight individuals, respectively. In addition, the inverse correlation detected in normal-weight individuals ($r = -0.321$; $P < 0.05$) between fractional proximal tubular sodium reabsorption and dietary sodium intake was disrupted in overweight/obese individuals ($r = 0.058$; $P = \text{NS}$). The independent determinants of 24 h urinary sodium excretion were body mass index (BMI), the occurrence of antihypertensive treatment, and frequency of consumption of pasta and cold cuts.
Conclusions: Habitual salt intake in this sample of male adult population in southern Italy was well above the recommended amounts. A higher salt intake and an altered renal sodium handling were observed in overweight and obese participants. Sodium intake was only slightly reduced in hypertensive participants on pharmacological therapy.
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Keywords: dietary sodium intake; anthropometry; overweight/obesity; blood pressure

Introduction

The importance of dietary sodium intake in determining blood pressure (BP) and the incidence of hypertension is well established (INTERSALT, 1988; Law *et al*., 1991) and many epidemiological studies have shown that high salt intake is associated with an increased risk of high BP. In the INTERSALT study, the association between BP and sodium intake was studied in 52 communities in a wide range of salt intake (INTERSALT, 1988). The study showed that a direct, significant association existed between the increase in BP with age and sodium intake. Other available observational studies documented a strong positive association between dietary sodium and BP within and between populations (Frost *et al*., 1991; Law *et al*., 1991).

The efficacy of reducing sodium intake in lowering BP was thoroughly analyzed and the results of randomized trials

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(He and MacGregor, 2002; Geleijnse *et al*., 2003) of sodium reduction in people with and without hypertension have come in support of the observational findings. The DASH-sodium Collaborative Research Group showed that reducing sodium intake to 40 mmol/day (2.3 g) is effective in reducing BP in the short term in hypertensive patients in a dose-response manner (Sacks *et al*., 2001).

Five large randomized trials showed that in subjects with high–normal BP also, a reduction in dietary sodium produced a significant, although modest, effect on BP (Stamler *et al*., 1989).

Finally, in a Cochrane systematic review (including 17 trials in individuals with elevated BP and 11 trials in individuals with normal BP), a modest reduction in salt intake (on average 2 g/day) for 4 weeks or more, was effective in reducing BP with possible effect on disease prevention (He and Mac Gregor, 2004).

The effects of changes in dietary sodium intake have also been analyzed in relation to other primary end points. A significant direct association between sodium intake and stroke has been indeed reported. Among overweight people, a difference in the sodium content of the diet of 100 mmol/day was associated with an 89% increase in stroke mortality (He *et al*., 1999). A positive, statistically significant association between sodium intake and death from ischemic stroke was also described by Nagata *et al*. (2004).

In addition, habitual urinary sodium excretion (a good estimate of dietary sodium intake) was significantly and positively associated with mortality from cardiovascular disease; the hazards ratios for coronary heart disease, cardiovascular disease and all-cause mortality associated with a 100 mmol higher 24 h urinary sodium excretion (UNa) were 1.51, 1.45 and 1.26, respectively (Tuomilehto *et al*., 2001).

Taken together, the available data strongly support the need for a population approach to lower salt intake (Cappuccio *et al*., 1993) to prevent cardiovascular disease in the general population; nevertheless, only a few countries have adopted specific public health policies to reduce salt intake (Cappuccio, 2007).

Sodium intake is usually high in Italy, as in other western countries. Only a few studies have investigated this issue in the Italian population (Leclercq and Ferro-Luzzi, 1991) or at a regional level (Strazzullo *et al*., 1983). The aim of this study was to assess dietary sodium intake and its association with anthropometric indices, BP, renal sodium handling and nutritional factors in an adult male population in southern Italy (Olivetti Heart Study).

Materials and methods

The Olivetti Heart Study is an epidemiological investigation of cardiovascular risk factors carried out in southern Italy. The study started in 1975 with periodical follow-up for 30 years and involved the Olivetti factories male workforce (Olivetti Heart Study Official, www.olivettiheartstudy.org).

Data presented in this study were collected during the 2002–2004 follow-up examination; a total of 940 men in the age range of 25 to 75 years were examined. Participants underwent anthropometric measurements, blood tests, a fixed-sequence questionnaire including demographic information, past medical history and a food frequency questionnaire (FFQ).

The local ethics committee approved the study protocol, and participants gave their informed written consent to participate.

Anthropometric indices

Body weight and height were measured on a standard beam balance scale. Body weight was measured to the nearest 0.1 kg and height was measured to the nearest centimeter. The body mass index (BMI) was calculated as weight in kilograms divided by the square of the height in meters. According to BMI, participants were defined as normal weight (BMI of $<25\,kg/m^2$), overweight (BMI of $\geqslant 25$ and $<30\,kg/m^2$) or obese (BMI of $\geqslant 30\,kg/m^2$). Waist circumference was measured at the umbilicus level with the subject standing erect with the abdomen relaxed, arms at the sides and feet together. The measurements were performed to the nearest 0.1 cm with a flexible inextensible plastic tape. The arm circumference was measured at the mid-point between the acromion and the olecranon with the arm relaxed and hanging just away from the side of the body. Subscapular and triceps skinfold thicknesses were measured using a Lange skinfold calliper (Beta Technology Inc., Santa Cruz, CA, USA). The subscapular skinfold was measured just below the inferior angle of the scapula at 45° to the vertical, and the triceps skinfold midway between the tip of the olecranon and the acromion process of the scapula, at the back of the upper arm.

BP measurement

BP was taken after the subject had been sitting upright for at least 10 min. Systolic BP and diastolic (phase V) BP were measured with a random zero sphygmomanometer (Gelman Hawksley Ltd., Sussex, UK) three times at 2 min apart. The first reading was discarded, and the average of the last two readings was recorded. Hypertension was defined as systolic BP of $\geqslant 140$ mm Hg and/or diastolic BP of $\geqslant 90$ mm Hg or regular antihypertensive treatment (Phillips, 2003).

Blood sampling and biochemical assays

After the BP measurements, a fasting venous blood sample was taken in the seated position. The blood specimens were immediately centrifuged and stored at $-70\,^{\circ}C$ until analyzed. Glucose levels were measured with automated methods (Cobas-Mira; Roche, Milan, Italy). Urinary and serum creatinine were determined by picric acid colorimetric method (Jaffè) using Cobas-Mira analyzer.

Urinary sodium excretion
A 24-h urine collection was obtained from each participant for the measurement of sodium excretion to estimate daily dietary sodium intake. On the day before the visit, participants were instructed to discard the first urine of the morning of the collection and to save all urines voided for the following 24 h. Urine was collected in polypropylene bottles, and delivered to the laboratory for immediate storage of the samples at −80 °C. Urinary sodium concentration was measured by flame photometry. The 24 h urinary creatinine excretion was used as an estimate of the completeness of the collection: the participants whose urinary creatinine felt below the 5th percentile of the distribution (0.6 g creatinine/24 h) were excluded from the analysis.

Clearance of endogenous lithium
In a randomly selected subsample of participants ($n = 138$), renal tubular sodium handling was analyzed by the clearance of endogenous lithium. To this scope, serum and 24 h urine endogenous lithium levels were measured according to a standardized, previously validated procedure (Folkerd *et al*., 1995). Proximal tubular sodium reabsorption (FPRNa) was calculated as the percentage of glomerular filtration rate according to the standard formula: FPRNa = (lithium clearance/creatinine clearance) × 100.

Food frequency questionnaire
A semiquantitative FFQ, designed to ascertain in detail the quantities and kinds of food consumed over the previous year, was filled in by the participants at home during the days preceding the visit and checked for incongruence and missing items by a dietician during the day of the visit. The FFQ consisted of 120 food/beverage items; for each of them, a reference standard portion size was indicated using household measures, the weight (for example, pasta) or unit (for example, fruit) at purchase. The participants were asked to say whether the amount of food consumed was similar to that quantity or less (<50% of the reference portion) or more (>50% of the reference portion). The frequency of consumption of items could be specified by day (⩾1/day), week (from 1/week to 5–6/week) or month (⩽1/month or 2–3/month). From the FFQ data, the daily frequency of consumption of standard portion of the following foods/food groups was calculated: bread, pasta, meat, fish, canned meat and tuna, soft cheeses, hard cheeses and cold cuts. These foods/food groups were chosen as sodium-rich foods or largely consumed foods to which salt is added when eating (discretionary salt) (INRAN, 2003).

Statistical analysis
Statistical analysis was performed using the Statistical Package for Social Sciences (SPSS-PC; SPSS Inc., Chicago, IL, USA). Percentiles of UNa were calculated in the population as a whole and in specific subgroups: 5th, 10th, 25th, 50th, 75th, 90th and 95th were reported. Urinary sodium distribution was compared between groups using Student's *t*-test for unpaired data. Pearson's linear correlation was used to detect bivariate associations. Analysis of variance was used to assess differences between group means. Chi-square analysis was used to compare the frequencies across categories. Linear regression analysis was used to evaluate the independent determinants (namely BMI, occurrence of antihypertensive treatment and frequency of consumption of standard portions of bread, pasta, meat, fish, canned meat and tuna, soft cheeses, hard cheeses and cold cuts) of UNa. All variables but antihypertensive treatment (yes/no) were continuous ones. Results were expressed as mean ± s.d. or mean and 95% confidence intervals, or median and range as indicated. Two-sided $P < 0.05$ was considered statistically significant.

Results

Table 1 shows the characteristics of the participants. The population included a large proportion of overweight (56.1%) and obese (20.6%) individuals. In total, 71% of the participants were hypertensive: the majority of these (52%) regularly took antihypertensive medications at the time of the examination.

The 24 h UNa averaged 203 ± 70 mmol/day (corresponding to a dietary intake of 11.5 g/day) with a large inter-individual variability. UNa was normally distributed in the entire population and ranged from 52.4 to 409.6 mmol/day. The 10th percentile corresponded to 116.1 mmol/day, and the 90th to 299.2 mmol/day. A total of 94.4% of the population showed urinary sodium values above the daily sodium intake (100 mmol/day) recommended by the Italian Guidelines for the general population (INRAN, 2003).

Subgroup analyses of the UNa frequency distribution are presented in Table 2. Comparisons were made between participants below or above the population median for age (59 years), between normal-weight and overweight/obese participants, normotensive and hypertensive participants and untreated hypertensive and treated hypertensive patients. Significantly higher UNa ($P < 0.05$) was observed in overweight/obese and untreated hypertensive participants in comparison to normal-weight and treated hypertensive individuals, respectively.

No significant associations were found between UNa and systolic or diastolic BP, both in the population as a whole and in the subgroup of those not taking antihypertensive medications ($0.021 > r < 0.080$, $P > 0.05$ age adjusted).

UNa was significantly and directly related to BMI and to umbilical and arm circumferences ($0.129 > r < 0.139$,

Table 1 Baseline characteristics of participants ($n = 940$)

	M ± s.d.	Median	Range
Age, years	59.7 ± 6.7	59.0	32–81
Height, cm	166.5 ± 6.1	166.5	148.8–188.4
Weight, kg	76.0 ± 10.9	75.4	47.0–114.6
BMI, kg/m^2	27.4 ± 3.4	27.1	17.9–40.1
Serum cholesterol, mg per 100 ml	215.6 ± 39.4	212.5	104–417
Serum triglyceride, mg per 100 ml	130.4 ± 67.8	116.5	26–682
Serum HDL cholesterol, mg per 100 ml	46.6 ± 11.7	45.0	19–96
Serum LDL cholesterol, mg per 100 ml	142.9 ± 36.6	141.0	22–364
Serum glucose, mg per 100 ml	103.2 ± 28.3	96.0	48–297
Systolic BP, mm Hg	138.8 ± 15.5	137	99–205
Diastolic BP, mm Hg	89.7 ± 9.5	89.0	62–131
Urine volume, ml/24 h	1537 ± 485	1500	500–2880
Urinary creatinine, g/24 h	1.5 ± 0.4	1.5	0.6–3.3
Urinary sodium excretion, mmol/24 h	203.2 ± 70.5	194.8	52.4–409.6

Abbreviations: BMI, body mass index; BP, blood pressure; HDL, high-density lipoprotein; LDL, low-density lipoprotein.

Table 2 Percentiles of 24 h UNa excretion by categories of selected variables

	Percentiles 24 h UNa (mmol/day)							P-value
	5th	10th	25th	50th	75th	90th	95th	
Age ⩽59 years ($n = 470$)	95.3	117.3	154.2	192.4	244.5	300.8	334.0	
Age >59 years ($n = 470$)	99.0	115.3	153.0	201.5	246.3	296.9	344.2	
Normal weight ($n = 225$)	97.6	105.6	149.9	189.5	231.1	275.2	304.5	<0.05
Overweight/obese ($n = 715$)	97.4	117.8	154.6	198.0	250.8	306.6	345.4	
Normotensives ($n = 277$)	99.4	119.1	160.2	207.0	250.7	302.5	334.4	
Hypertensives ($n = 663$)	94.9	115.8	151.6	192.9	243.4	296.0	344.3	
Untreated hypertensive ($n = 315$)	99.1	118.9	157.1	201.0	252.1	301.9	336.3	<0.05
Treated hypertensive ($n = 348$)	93.7	113.8	145.1	188.2	235.6	295.1	333.1	

Abbreviation: UNa, urinary sodium.

$P<0.01$). No association was detected with tricipital and subscapular skinfolds. Only 7% of normal-weight individuals (BMI of <25 kg/m^2) had a UNa of <100 mmol/day.

The relationships between UNa and FPRNa were evaluated in a randomly selected sample of 138 men, stratified as normal-weight ($n = 33$) and overweight/obese participants ($n = 105$). As shown in Figure 1a, in normal-weight participants an inverse, statistically significant association was observed between FPRNa and UNa ($r = -0.321$, $P<0.05$). In contrast, no such association was detected in overweight or obese patients (Figure 1b; $r = 0.058$; $P =$ NS).

The frequency of consumption of selected foods or food groups ranged from 0.09 ± 0.09 standard portions/day for canned food to 2.0 ± 0.6 standard portions/day for bread. On average, for the other foods considered (meat, fish and sea foods, cold cuts and hard and soft cheeses), the frequency of consumption was 0.5 standard portions/day, whereas that of pasta was 1 portion/day. In a multiple linear stepwise regression model, UNa was significantly and independently associated with BMI, occurrence of antihypertensive therapy and frequency of consumption of standard portions of pasta and cold cuts. No statistically significant associations (Table 3) were observed between daily UNa and the frequency of consumption of standard portions of bread, canned food, meat, fish and soft cheeses and hard cheeses.

Discussion

This study evaluated the distribution of estimated dietary sodium intake in a large unselected sample of adult male population in southern Italy. We found that the dietary intake of sodium, as estimated by 24 h UNa, averaged approximately 12 g NaCl/day, a value well above that recommended (5 g NaCl/day) by dietary guidelines of the Italian Institute for Food Research and Nutrition (INRAN, 2003) for the general population.

Our findings were in line with previous data on dietary sodium intake in Italy in adults; mean UNa was 175 mmol sodium/day in the INTERSALT study (INTERSALT, 1988), whereas another study reported a mean dietary sodium intake of 160 mmol/day in women and 190 mmol/day in

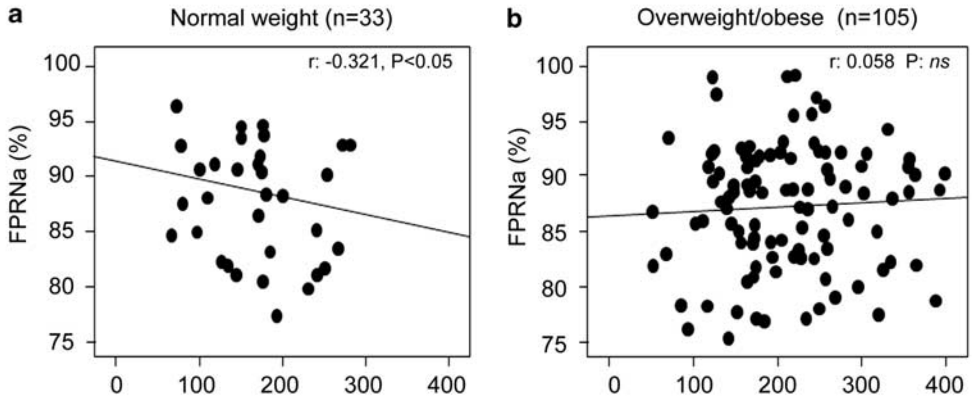

Figure 1 Relationships between fractional proximal sodium reabsorption (FPRNa) and urinary sodium excretion (UNa) in normal weight (**a**) or overweight/obese (**b**) individuals.

Table 3 Stepwise regression analysis: 24 h UNa excretion and selected variables

Variables	*B*	*95% CI*	P-*value*
BMI	0.127	0.104–0.150	0.0001
Frequency of consumption of standard portions of pasta	0.091	0.070–0.111	0.01
Antihypertensive treatment	0.084	0.065–0.103	0.017
Frequency of consumption of standard portions of cold cuts	0.078	0.057–0.097	0.028

Abbreviations: BMI, body mass index; UNa, urinary sodium; B, β standardized coefficient; 95% CI, 95% confidence interval.
Only statistically significant variables were shown: variables excluded were frequency of consumption of standard portions of bread, meat, fish, canned food and cheese.
All continuous variables but antihypertensive treatment (yes/no).

men (Leclercq and Ferro-Luzzi, 1991). Interestingly, dietary sodium intake had been previously evaluated in a subgroup in the Olivetti Heart Study in 1976 (Strazzullo *et al*., 1983), when the average estimated sodium intake was 180 mmol/day, which is very similar to the current intake. Thus, it seems as if, over the past two decades, information and awareness campaigns about the importance of the reduction of dietary sodium intake failed to reach this population.

No association was found between individual BP and UNa values in our study population. This finding was not surprising, in the first place because the population under study included a large proportion of hypertensive patients. In addition, most of these patients were on regular antihypertensive treatment. Finally, the large regression dilution bias, affecting both the BP and, more so, the urinary sodium intake estimates, reduced the possibility to detect true biological correlations. Nonetheless, our findings about sodium intake in hypertensive patients are noteworthy: the JNC 7 guidelines (Phillips, 2003) recommended to maintain a daily sodium intake below 6 g NaCl/day. The mean daily sodium intake of hypertensive patients participating in the present study was well above the suggested intake. It can be speculated that awareness of the presence of disease and the subsequent implementation of dietary measures to help to maintain BP control has favored the lower dietary sodium intake observed in the subgroup of treated hypertensive patients, although it was apparent that even these motivated individuals remained quite far from reaching the desirable level of dietary salt intake.

In the Olivetti Heart Study population, sodium excretion was significantly associated with anthropometric indices of adiposity. In particular, BMI was the first independent determinant of daily dietary sodium intake. Overweight and obese participants showed higher UNa in comparison to normal-weight individuals. Previous studies from our group suggested that abnormalities in renal tubular sodium handling may occur in overweight and obese individuals (Strazzullo *et al*., 2001, 2006); in particular, in these individuals, an enhanced FPRNa was detected, possibly leading to extracellular fluid volume expansion and high BP. It has been shown that proximal tubular sodium handling is strictly dependent on sodium intake (Strazzullo *et al*., 1988). On a low-sodium diet, renal electrolyte homeostasis is maintained by enhancing the renal tubular sodium reabsorption at proximal sites, whereas reabsorption is reduced upon increase in sodium intake. The evaluation of renal segmental tubular sodium handling in the present study showed that in normal-weight individuals, the physiological regulation of sodium reabsorption at the proximal tubule (Strazzullo *et al*., 1988) is maintained; that is, the higher the sodium intake, the lower its reabsorption at the proximal tubule. In contrast, in overweight/obese individuals the control of tubular sodium handling seems to be altered, being independent of the total amount of sodium ingested. Under these circumstances, our findings support the concept that reduction of dietary sodium should be particularly effective in overweight/obese individuals as they combine the attitude to consume more salt with a reduced ability to excrete the excess dietary sodium. Unfortunately, our study showed that among normal-weight participants, only 7% had a UNa below the recommended level of 100 mmol/day: this percentage fell to 5% among overweight/obese participants.

In the present study, the role of nutritional factors was also evaluated. In particular, we analyzed the relationships between dietary sodium intake and the frequency of consumption of specific food items/groups, chosen for their high salt content or because they were consumed daily or in large amounts. Among those selected, pasta and cold cuts were independent determinants of dietary sodium intake. The salt content of pasta strictly depends upon added (discretionary) salt. Previous studies (Leclercq and Ferro-Luzzi, 1991) showed that discretionary salt constitutes >30% of total dietary sodium intake in Italian adults. Our findings could be probably explained by the attitude to add salt to pasta while cooking and have additional relevance because pasta in Italy is consumed daily and usually in large amounts. Cold cuts are foods rich in salt due to food-processing techniques, and although they were not the sole sodium-rich foods included in the analysis, the frequent consumption of these particular foods makes them important in determining the total dietary sodium intake.

The present study has several limitations. First, this analysis was carried out in male subjects only in a restricted geographical area, and hence that our findings cannot be extrapolated to the entire Italian population. In addition, as the population under study was composed of middle-aged men, it was not representative of younger individuals. The latter, however, might offer some advantages, in particular the possibility to evaluate the characteristics of sodium intake in a period of life with a high prevalence of diseases, such as overweight/obesity and hypertension, which may benefit more from the reduction of dietary sodium intake. In addition, UNa was assessed by single 24 h urine collections: this introduced a large regression dilution bias leading to the risk of misclassification of dietary sodium intake at the individual level. Nevertheless, this limitation should not impair a correct description of the general attitudes of the population toward sodium chloride intake, which was the main objective of our study (WHO, 2006).

Substantial cooperation among institutions, food industry, clinicians and public will be required to enable a larger proportion of the population to experience the benefits of reduced dietary sodium. With an appropriate food industry response, counseling of patients and public education, sodium intake could be reduced; it is noteworthy that at the population level, a moderate reduction would be a feasible and effective objective to be pursued (Barba, 2008). Special attention should be paid to subgroups such as overweight and obese who would benefit to a greater extent by the reduction in sodium intake. Further studies are required in larger populations to assess the differences and similarities in sources of sodium from the diet to implement strategies to lower dietary sodium intake according to the currently available guidelines for disease prevention in the general population.

Conflict of interest

The authors declare no conflict of interest.

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