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► **To cite this version:**

P Strazzullo, Antonella Venezia, Gianvincenzo Barba, Ornella Russo, Clemente Capasso, et al.. DIETARY SODIUM INTAKE IN A SAMPLE OF ADULT MALE POPULATION IN SOUTHERN ITALY. Results of the Olivetti Heart Study. European Journal of Clinical Nutrition, 2010, n/a (n/a), pp.n/a-n/a. 10.1038/ejcn.2010.22 . hal-00516533

**HAL Id: hal-00516533**

**<https://hal.science/hal-00516533>**

Submitted on 10 Sep 2010

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**DIETARY SODIUM INTAKE IN A SAMPLE OF ADULT MALE  
POPULATION IN SOUTHERN ITALY.  
Results of the Olivetti Heart Study**

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***Short title: Sodium intake in southern Italy***

**Wordcount of abstract: 244**

**Wordcount of the text: 3046**

**Number of figures: 1**

**Numbers of tables: 3**

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**Conflict of interest: None**

## **Abstract**

**Objective:** To assess dietary habitual sodium intake, 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.

**Design, Setting and Participants:** The study population was composed of 940 men participating in the 2002-04 follow-up examination of the Olivetti Heart Study. Blood pressure, anthropometric indices, biochemical parameters and sodium excretion in a 24h urine collection were measured. The frequency of consumption of selected foods was estimated by a food frequency questionnaire capturing the previous year. 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 24h urinary excretion was  $203 \pm 70$  mmol/day. Sodium excretion was significantly lower in treated hypertensive patients and higher in overweight/obese participants as compared to 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 ( $r = 0.058$ ;  $P = \text{n.s.}$ ). The independent determinants of 24h urinary sodium excretion were body mass index 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.

**Key words:** 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 demonstrated 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 (Law et al, 1991; Frost et al, 1991).

The efficacy of reducing sodium intake in lowering BP was thoroughly investigated and the results of randomised trials (Geleijmse et al, 2003; He & Mac Gregor, 2002) 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 fashion (Sacks et al, 2001).

Five large randomised trials showed that, also in subjects with high-normal BP, 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 impact on disease prevention (He & McGregor, 2004).

The effects of changes in dietary sodium intake have been investigated also in relation to other primary endpoints. A significant direct association between sodium intake and stroke has been indeed reported. Among overweight persons, 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) in order to prevent cardiovascular disease in the general population; nevertheless, only a few countries have adopted specific public health policies to reduce salt intake (Cappuccio et al, 2007).

Sodium intake is usually high in Italy, as in other western Countries. Only a few studies investigated this issue in the Italian population (Leclercq et al, 1991) or at regional level (Strazzullo et al, 1986). The aim of the present 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).

## **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 ([www.olivettiheartstudy.org](http://www.olivettiheartstudy.org)).

Data presented here were collected during the 2002-04 follow-up examination; a total of nine-hundred forty men in the age range 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.

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 at the nearest 0.1 kg and height was measured at the nearest centimetre. 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 ( $\text{BMI} < 25 \text{ kg/m}^2$ ), overweight ( $\text{BMI} \geq 25$  and  $< 30 \text{ kg/m}^2$ ), or obese ( $\text{BMI} \geq 30 \text{ kg/m}^2$ ). 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 at 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 by a Lange skinfold calliper (Beta Technology Inc., Santa Cruz, CA). The subscapular skinfold was measured just below the inferior angle of the scapula at  $45^\circ$  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 minutes. Systolic and diastolic (phase V) BP was measured with a random zero sphygmomanometer (Gelman Hawksley Ltd., Sussex, United Kingdom) three times, 2 minutes apart. The first reading was discarded, and the average of the last two readings was recorded. Hypertension was defined as systolic BP $\geq$ 140 mmHg and/or diastolic BP $\geq$ 90 mmHg 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 °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 24h 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 24h. Urine were collected in polypropylene bottles, delivered to the laboratory for immediate storage of the samples at -80°C. Urinary sodium concentration was measured by flame photometry. Twenty-four hour urinary creatinine excretion was used as an estimate of the completeness of the collection: the participants whose urinary creatinine fell below the 5<sup>th</sup> percentile of the distribution (0.6 g creatinine/24h) were excluded from the analysis.

### ***Clearance of endogenous lithium***

In a randomly selected subsample of participants (n=138), renal tubular sodium handling was investigated by the clearance of endogenous lithium. To this scope, serum and 24h urine endogenous lithium levels were measured according to a standardised, previously validated, procedure. Proximal tubular sodium reabsorption (FPRNa) was calculated as percent of glomerular filtration rate according to the standard formula:  $FPRNa = (\text{lithium clearance} / \text{creatinine clearance}) * 100$ .

### ***Food frequency questionnaire***

A semiquantitative food frequency questionnaire (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 questionnaire consisted of 120 food/beverage items; for each of them, a reference standard portion size was indicated using household measures, the weight (eg, pasta) or unit (eg, 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 ( $\geq 1/\text{day}$ ), week (from 1/week to 5-6/week), or month ( $\leq 1/\text{month}$  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, 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, Illinois, USA). Percentiles of UNa were calculated in the population as a



whole and in specific subgroups: 5<sup>th</sup>, 10<sup>th</sup>, 25<sup>th</sup>, 50<sup>th</sup>, 75<sup>th</sup>, 90<sup>th</sup> and 95<sup>th</sup> were reported. Urinary sodium distribution was compared between groups by Student's t- test for unpaired data. Pearson linear correlation was used to detect bivariate associations. Analysis of variance (ANOVA) 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, frequency of consumption of standard portions of bread, pasta, meat, fish, canned meat and tuna, soft cheeses, hard cheeses, cold cuts) of UNa. All variables but antihypertensive treatment (yes/no) were continuous ones. Results were expressed as mean±SD or mean and 95% confidence intervals (95% CI), 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. Seventy-one % of the participants were hypertensive: the majority of these (52%) regularly took antihypertensive medications at the time of the examination.

Twenty-four hour UNa averaged  $203 \pm 70$  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 10<sup>th</sup> percentile corresponded to 116.1 mmol/day, and the 90<sup>th</sup> to 299.2 mmol/day. 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 yrs), between normal weight and overweight/obese participants, normotensive and hypertensive participants, 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 ( $0.129 > r < 0.139$ ,  $P < 0.01$ ). No association was detected with tricipital and subscapular skinfolds. Only 7% of normal weight individuals ( $BMI < 25 \text{ Kg/m}^2$ ) had a UNa  $< 100$  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 1 (panel A), in normal weight participants an inverse, statistically significant, association was observed between FPRNa and UNa ( $r=-0.321$ ,  $P<0.05$ ). By contrast, no such association was detected in overweight or obese patients (panel B;  $r=0.058$ ;  $P=n.s.$ ).

The frequency of consumption of selected foods or food groups ranged from  $0.09\pm 0.09$  standard portions/day for canned food to  $2.0\pm 0.6$  standard portions/day for bread. On average, for the other foods considered (meat, fish and sea foods, cold cuts, hard and soft cheeses), the frequency of consumption was 0.5 standard portions/day, whilst 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, 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, soft cheeses and hard cheeses.

## **DISCUSSION**

The present 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 24h 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 Na/day in the INTERSALT study (INTER-SALT, 1988), whilst another study reported a mean dietary sodium intake of 160 mmol/day in women and 190 mmol/day in men (Leclercq et al, 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, very similar to the current intake. Thus, it appears as if, over the last 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 et al, 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 favoured 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; Strazzullo et al, 2006); in particular, in these individuals, an enhanced FPRNa was detected, possibly leading to extracellular fluid volume expansion and high BP. It has been demonstrated 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, i.e. 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 appears 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 analysed the relationships between dietary sodium intake and the frequency of consumption of specific food items/groups, chosen for their high salt content or because 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 et al, 1991) showed that discretionary salt constitutes more than 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; 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 of all, the present analysis was carried out -in male subjects only- in a restricted geographical area, so 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, that may benefit more from the reduction of dietary sodium intake. In addition, UNa was assessed by single 24h urine collections: this introduced a large regression dilution bias leading to the risk of misclassification of dietary Na intake at the individual level. Nevertheless, this limitation should not impair a correct description of the general attitudes of the population towards NaCl intake, 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, counselling of patients and public education, sodium intake could be reduced; of note, at the population level, a moderate reduction would be a feasible and effective objective to be pursued (Barba G, 2008). Special attention should be paid to subgroups like overweight and obese who would benefit to a greater extent of the reduction of

sodium intake. Further studies are required in larger populations to assess the differences and similarities in sources of sodium from the diet in order to implement strategies to lower dietary sodium intake according to the currently available guidelines for disease prevention in the general population.

**Aknowledgement**

The present paper has been developed within the activities of the InterSocietal Working Group for the Reduction of Salt Intake in Italy (Co-ordinator Prof. Pasquale Strazzullo, [www.menosalepiusalute.org](http://www.menosalepiusalute.org)).



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**Table 1.** Baseline characteristics of participants (n= 940)

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

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

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

UNa= urinary sodium

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

<b>Variables</b>	<b>B</b>	<b>95% C.I.</b>	<b>P</b>
BMI	0.127	0.104 - 0.150	0.0001
<b>Frequency of consumption of standard portions of pasta</b>	0.091	0.070 – 0.111	0.01
Antihypertensive treatment	0.084	0.065 – 0.103	0.017
<b>Frequency of consumption of standard portions of cold cuts</b>	0.078	0.057 – 0.097	0.028

B= Beta standardized coefficient; 95% C.I. = 95% Confidence Intervals.

**Only statistically significant variables were shown:** variables excluded=frequency of consumption of standard portions of bread, meat, fish, canned food, cheese.

All continuous variables but antihypertensive treatment (yes/no)

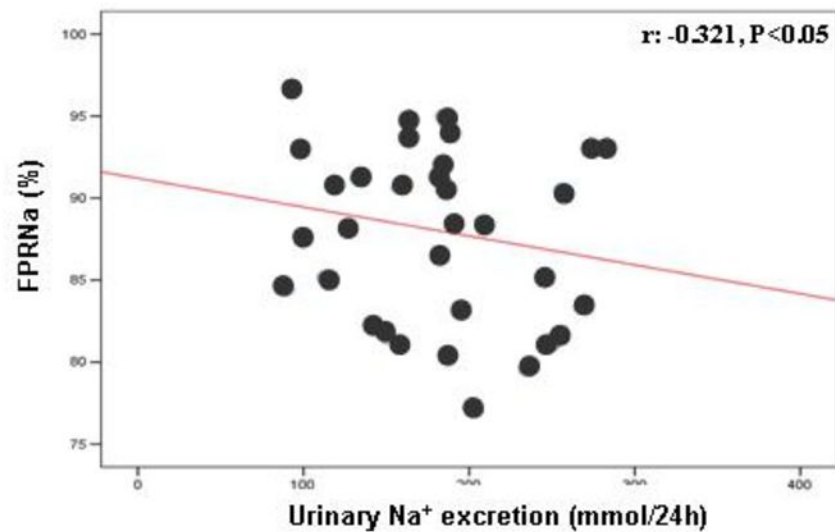
**Figure legend**

**Figure 1.** Relationships between fractional proximal sodium reabsorption and urinary sodium excretion according to the degree of adiposity.

FPRNa = fractional proximal sodium reabsorption; UNa = urinary sodium excretion



A) Normal weight (n=33)



B) Overweight/obese (n=105)

