The effect of dietary sodium intake on biochemical markers of bone metabolism in young women

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To investigate the effect of a low (80 mmol/d) or high (180 mmol/d) Na intake for 14 d on biochemical markers of bone turnover in Na-sensitive and Na-non-sensitive healthy young women, twenty-nine subjects were screened for responsiveness of urinary Ca excretion to increasing dietary Na intake (40, 80, 120 and 200 mmol/d for 7 d). In a crossover study, the eight Na-sensitive and eight of the twenty-one Na-non-sensitive subjects were randomly assigned to diets containing either 80 or 180 mmol Na/d for 14 d followed by crossover to the alternative diet for a further 14 d. Dietary Ca was restricted to 12·5 mmol/d throughout. During each dietary period, fasting morning first void urine samples (last 3 d) and fasting blood serum samples (morning of twelfth day) were collected. Increasing Na intake from 80 to 180 mmol/d increased urinary Na about twofold in both the Na-sensitive and Na-non-sensitive groups and increased urinary Ca excretion (by 73 %) in the Na-sensitive group only. Biochemical markers of bone resorption (urinary pyridinoline and deoxypyridinoline) and bone formation (serum osteocalcin and bone-specific alkaline phosphatase; *EC* 3.1.3.1) were unaffected by increasing dietary Na in either group. It is concluded that the Na-induced calciuria observed in the Na-sensitive healthy young women did not result in increased bone resorption or turnover and, despite restricted Ca intake, adaptation of dietary Ca absorption may have compensated for the increased urinary Ca loss.

Sodium: Bone: Biochemical markers: Premenopausal women

There is evidence that high dietary Na intake may have adverse effects on bone metabolism and may be a risk factor for osteoporosis. Increasing Na intake within the range of usual dietary intakes is associated with increased urinary Ca loss (Aub *et al.* 1937; Hills *et al.* 1959; King *et al.* 1964; Kleeman *et al.* 1964; Shortt *et al.* 1988; Shortt & Flynn, 1990). It has been estimated that a 100 mmol increment in daily Na intake is associated with an average loss of urinary Ca of approximately 1 mmol in free-living normocalciuric healthy populations (Nordin *et al.* 1993). There is also a large inter-individual variation in Na-induced calciuria ranging from a strong response in some individuals to no detectable response in others (Shortt *et al.* 1988). It is not known to what extent Na-induced calciuria is compensated for by increased absorption of dietary Ca or to what extent this Ca is derived from resorption of bone (Shortt & Flynn, 1990).

There is evidence that very high Na intakes reduce bone mass and bone Ca content in rats (see review by Shortt & Flynn, 1990). However, the limited number of studies which have investigated the association of dietary Na with bone mineral density in human subjects have produced conflicting results (Nordin & Polley, 1987; Greendale *et al.* 1994; Devine *et al.* 1995; Matkovic *et al.* 1995).

There is also evidence that urinary hydroxyproline, a marker of bone resorption, is increased with increasing Na intake (Goulding, 1981; Goulding & Lim, 1983; Nordin & Polley, 1987; McParland *et al.* 1989; Need *et al.* 1991; Itoh & Suyama, 1996). However, urinary hydroxyproline has been shown to lack sensitivity and specificity as an indicator of bone resorption and urinary pyridinium cross-links of collagen are considered to be more reliable biochemical markers of bone resorption (Delmas, 1992; Leitz *et al.* 1997).

Abbreviations: Cr, creatinine; Dpyr, deoxypyridinoline; PTH, parathyroid hormone; Pyr, pyridinoline.

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Two recent studies have investigated the effects of dietary Na on urinary pyridinium crosslinks of collagen. Lietz *et al.* (1997) showed that there was no significant difference in deoxypyridinoline (Dpyr) excretion in postmenopausal women consuming a fixed diet containing either high (170 mmol/d) or low (60 mmol/d) levels of Na for 8 d while on a fixed Ca intake (20 mmol/d). Evans *et al.* (1997) reported that urinary excretion of Dpyr was higher following 7 d on a high-Na diet (300 mmol/d) than a low-Na diet (50 mmol/d) for postmenopausal but not premenopausal women. However, neither of these studies considered the large inter-individual variation in Na-induced calciuria which has been reported to occur.

Thus, the objectives of the present study were to investigate the effect of dietary Na on biomarkers of bone metabolism in healthy human subjects and to examine the influence of the responsiveness of urinary Ca to changing dietary Na intake on this.

Methods

Subjects

Twenty-nine young healthy adult females (mean age 24·5 (range 22–28) years) were recruited from among a group of postgraduates at University College, Cork. The mean height, weight and BMI of the subjects are provided in Table 1. The subjects were healthy without any history of bone or articular disease, and with no intake of medicine that could affect bone or cartilage metabolism. Additional exclusion criteria included chronic illness or established or familial history of hypertension. Subjects were requested to avoid vigorous exercise and excessive alcohol intake for the duration of the study.

Ethical considerations

Before participation in this study, all subjects signed an informed consent document approved by the Clinical Research Ethics Committee of the Cork Teaching Hospitals.

Design

The study consisted of a randomized crossover trial of the effect of 'low' (80 mmol/d) or 'high' (180 mmol/d) Na intake for 14 d on biochemical markers of bone turnover in subjects selected on the basis of the responsiveness or non-responsiveness of urinary Ca to dietary Na (Fig. 1).

Table 1. Characteristics of the group of healthy young adult female volunteers (*n* 29) who were screened for responsiveness of urinary calcium to dietary sodium

(Mean values with their standard errors, and range)

	Mean	SEM	Range
Age (years)	24·5	0·5	22–28
Height (m)	1·65	0·06	1·52–1·76
Weight (kg)	58·5	1·1	50–70
BMI (kg/m^2)	21·5	0·3	18·2–25·9

To screen subjects for responsiveness of urinary Ca to dietary Na, twenty-nine subjects consumed, for 7 d each, four diets which were formulated to contain varying levels of Na in the following order: 40, 80, 120 and 200 mmol/d while maintaining dietary Ca intake at 12·5 mmol (500 mg)/d (Shortt *et al.* 1988). Subjects were instructed to consume each diet for 7 consecutive days and a period of 5 d elapsed between each dietary regimen. Subjects were instructed to collect fasting first morning void urine samples and to complete a 24 h diet recall of food intake for each of the last 3 d of the different dietary regimens. Urine samples were analysed for Na, Ca and creatinine (Cr) and the urinary Ca concentration, Cr-corrected (Ca/Cr), was plotted against urinary Na concentration, also Cr-corrected (Na/Cr), for each subject. The relationship between urinary Ca/Cr and urinary Na/Cr was analysed by single linear regression analysis and Pearson's correlation coefficients for each subject. Subjects were categorized as 'Na sensitive' or 'Na-non-sensitive' on the basis of the presence or absence of statistical significance for this relationship (Fig. 2). On this basis eight Na-sensitive and eight Na-non-sensitive subjects were selected.

Following the screening period, selected subjects continued to consume the Ca-controlled diet (12·5 mmol/d) with no control of Na intake for 1 week, after which time they took part in the randomized crossover design Na intervention trial.

The Na intervention trial was designed in two periods, each of 14 d, in which the Na intakes were manipulated to be 80 or 180 mmol Na/d (Shortt *et al.* 1988) while Ca intake was maintained at 12·5 mmol/d. Na-sensitive and Na-non-sensitive subjects were randomly assigned to low- or high-Na diet regimens for 14 d followed by crossover to the alternative dietary regimen for a further 14 d (Fig. 1). Subjects were instructed to collect fasting first void urine samples between 07.00 and 09.00 hours for the last 3 d of each treatment period to allow a washout period as previously suggested (Shortt *et al.* 1988). The 24 h diet recalls for each individual were also obtained on each of these days. In addition, after an overnight fast, a blood sample (10 ml) was taken at 09.00 hours on the morning of the twelfth day of each dietary period.

Dietary analysis

Nutrient intakes were estimated from 24 h diet recall data for food consumption using the *McCance and Widdowson's The Composition of Foods* (Paul & Southgate, 1978) database (Microdiet, Salford, Greater Manchester, UK).

Collection and preparation of samples

Subjects were supplied with suitable collection containers for urine samples and asked to collect fasting first void morning urine samples between 07.00 and 09.00 hours each day for the last three consecutive days of each dietary

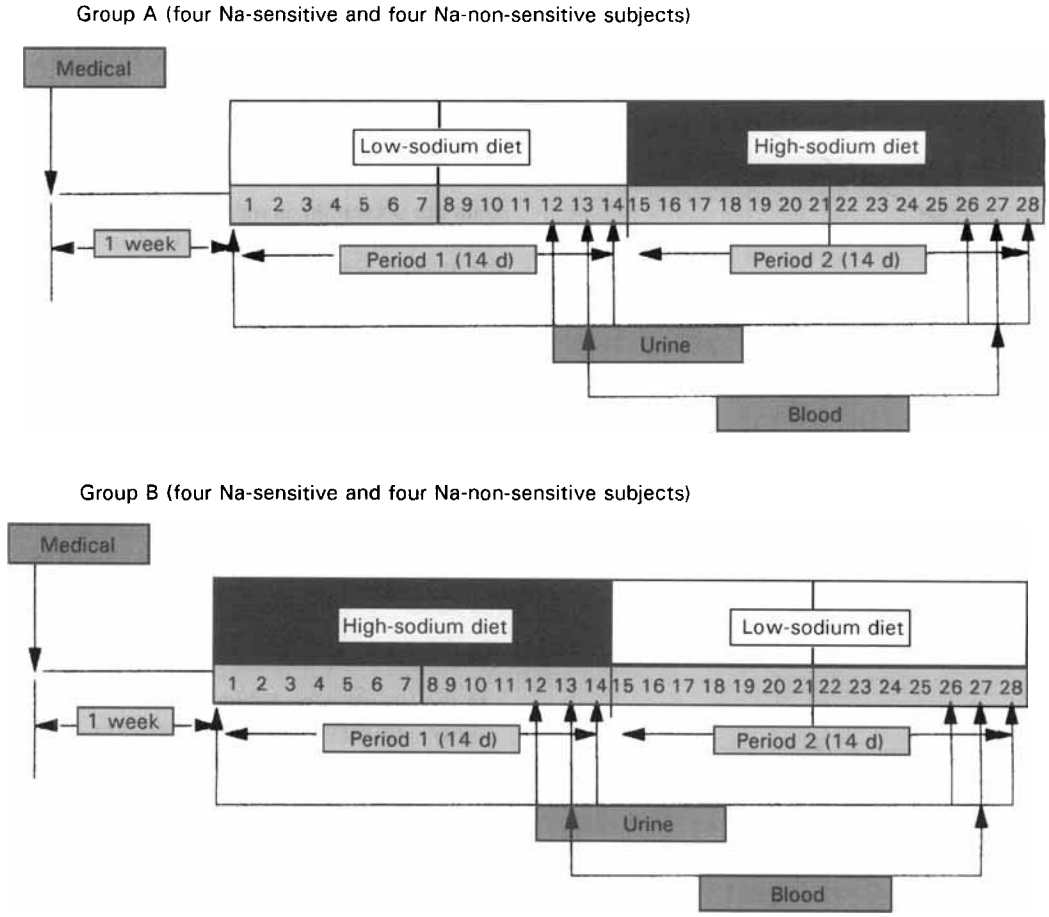

Fig. 1. Schedule of study design.

period. Portions of urine were stored at −20° from the morning of collection until required for analysis. Blood was collected by venepuncture into vacutainer tubes and was processed to serum which was immediately stored at −70° until required.

Experimental techniques

Urinary pyridinoline and deoxypyridinoline. Samples were analysed in duplicate using a three-step procedure. Urine was first hydrolysed with an equal volume of 12 M- HCl at 110° for 18 h, the crosslinks were then extracted by CF1 cellulose chromatography with the use of an internal standard (acetylated pyridinoline, MetraBiosystems Ltd, Wheatley, Oxon., UK) and were measured using a reversed-phase HPLC method with fluorescence detection (Colwell *et al.* 1993). The intra-assay CV for pyridinoline (Pyr) and Dpyr were 9 % and 13 % respectively. Interassay variation was avoided by analysing all samples from an individual in the same run.

Urinary creatinine. Fresh daily urine samples were analysed in duplicate by a colorimetric procedure using a diagnostic kit (catalogue no. 124 192; Boehringer Mannheim GmbH, Mannheim, Germany). The intra- and interassay CV were 3·2 % and 6·7 % respectively.

Urinary calcium, magnesium, sodium and potassium. Ca and Mg were analysed in duplicate in urine samples by atomic absorption spectrophotometry (Pye-Unicam Atomic Absorption Spectrophotometer, Model SP9, Cambridge, Cambs., UK) after appropriate dilution with $LaCl_3$ solution (5 g/l, BDH Ltd, Poole, Dorset, UK). A range of Ca and Mg standards were used to obtain Ca and Mg calibration curves. The intra- and interassay CV for Ca were 2·8 % and 7·8 %, and for Mg were 3·2 % and 8·8 % respectively. Na and K were determined in the urine samples by flame photometry (Model 435/455, Evans Electroselenium Ltd, Halstead, Essex, UK) using appropriate Na and K standards. The intra- and interassay CV for Na were 3·8 % and 6·9 %, and for K were 4·5 % and 9·3 % respectively.

Urinary cyclic AMP. Cyclic AMP was measured in first morning void urine samples using an ELISA (Amersham International, Amersham, Bucks., UK). The intra-assay CV was 7·6 % and interassay variation was avoided by analysing all samples from an individual in the same run.

Serum osteocalcin and bone-specific alkaline phosphatase. Serum bone-specific alkaline phosphatase (*EC* 3.1.3.1) levels were measured in serum samples using a recently developed ELISA (MetraBiosystems Ltd). The intra-assay CV was 4·5 %. Serum osteocalcin levels were measured in serum samples using an ELISA (BRI-

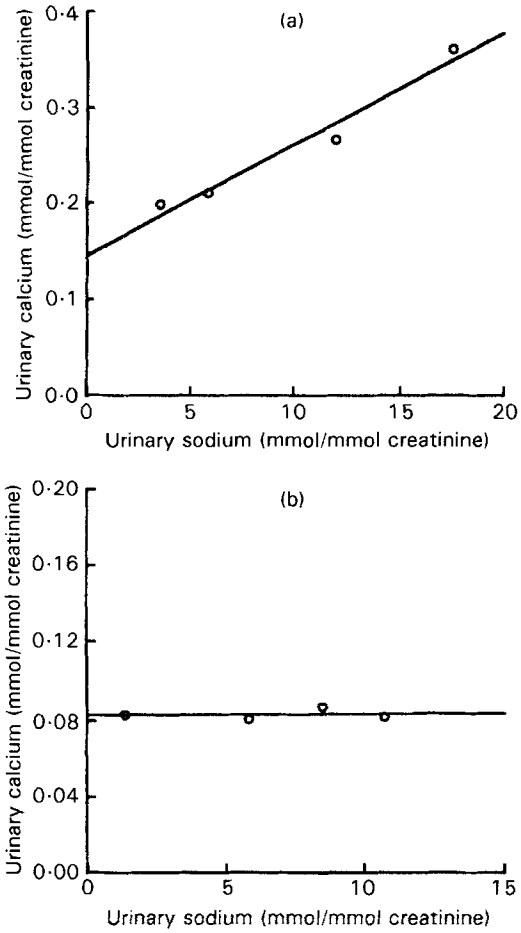

Fig. 2. Typical relationship between urinary calcium and urinary sodium, expressed relative to creatinine, in sodium-sensitive (a) and sodium-non-sensitive (b) individuals, on increasing dietary sodium intake from 40 mmol/d to 200 mmol/d and maintaining a constant Ca intake of 12·5 mmol/d. Panel (a): $y = 0{\cdot}14 + 0{\cdot}01x$, r 0·982. Panel (b): $y = 8{\cdot}21e^{-2} + 1{\cdot}27e^{-4}x$, r 0·176.

Diagnostics, Dublin 9, Ireland). The intra-assay CV was 11 %. Interassay variation for both serum osteocalcin and bone-specific alkaline phosphatase was avoided by analysing all samples from an individual in the same run.

Serum calcium and magnesium. Both Ca and Mg were analysed in duplicate in serum samples according to previously described methods (Trudeau & Freier, 1967; Pesce & Kaplan, 1987). The intra-assay CV were 3·1 % and 2·8 % respectively. There was no interassay variation as all samples from an individual were analysed in the same run.

Statistical analysis

Data are presented as means with their standard errors. The relationships between urinary Ca/Cr and urinary Na/Cr for the twenty-nine subjects were assessed by single linear regression analysis and Pearson's correlation coefficients.

Changes in the different biochemical indices during low- and high-Na periods in Na-sensitive and Na-non-sensitive groups were analysed by two-way ANOVA with the repeated measures design. Paired Student's t tests were used to compare the low- and high-Na diets in each group with respect to the various biochemical indices. Unpaired Student's t tests were used to compare the Na-sensitive and Na-non-sensitive groups either at low or high Na intakes with respect to the various biochemical indices.

Results

In the twenty-nine subjects who took part in the screening study urinary Ca increased on average by 0·66 mmol/100 mmol increase in urinary Na. Eight out of the twenty-nine subjects screened were deemed to be Na sensitive, i.e. their urinary excretion of Ca/Cr increased significantly ($P < 0{\cdot}05$) in response to increased Na intake. These eight subjects, together with eight subjects chosen randomly from the twenty-one subjects who were Na non-sensitive were selected for the intervention trial.

There was no significant difference between the Na-sensitive and Na-non-sensitive groups for age, weight, height or BMI (Table 2).

Dietary Ca intakes were similar during the low- and high-Na periods for both the Na-sensitive and Na-non-sensitive groups (Table 3). Similarly, there were no significant differences in the dietary intakes of energy, protein, P or K between the low- and high-Na dietary periods in either group or between the groups at either intake (Table 3).

The effects of increasing Na intake from 80 to 180 mmol/d for 14 d on serum and urinary biochemical variables are shown in Table 4. Urinary Cr concentration was similar for both Na-sensitive and non-sensitive groups and was unaffected by dietary Na intake. Urinary excretion of Na/Cr increased significantly ($P < 0{\cdot}05$) for both groups when Na intake was increased from 80 to 180 mmol/d.

Table 2. Characteristics of the sodium-sensitive and sodium-non-sensitive groups of young women selected for the intervention trial (Mean values with their standard errors)

	Na-sensitive (n 8)		Na-non-sensitive (n 8)		
	Mean	SEM	Mean	SEM	P value*
Age (years)	22·1	0·2	23·3	0·3	0·09
Height (m)	1·60	0·01	1·64	0·01	0·30
Weight (kg)	59·5	0·9	56·5	1·3	0·30
BMI (kg/m^2)	21·3	0·3	21·1	0·9	0·80

* Comparison of means between Na-sensitive and Na-non-sensitive groups using unpaired Student's t test.

Table 3. Mean daily nutrient intakes from the final 3 d during low- and high-sodium dietary periods for sodium-sensitive and sodium-non-sensitive groups of young women*

(Mean values with their standard errors)

	Na-sensitive (*n* 8)				Na-non-sensitive (*n* 8)			
	Low Na		High Na		Low Na		High Na	
Nutrient	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM
Energy (kJ)	7642	865	6933	422	6047	397	7396	602
Energy (kcal)	1864	211	1691	103	1475	97	1804	147
Protein (g)	48·8	4·9	55·0	4·8	53·7	4·4	61·7	4·9
Fibre (NSP)† (g)	10·8	1·2	8·9	1·1	9·8	0·7	12·3	2·4
Ca (mmol)	12·1	1·2	11·9	1·8	13·5	2·9	13·7	3·6
P (mmol)	27·6	2·3	27·3	2·7	27·5	2·5	31·3	3·8
K (mg)	2023	206	1904	203	2342	276	2755	299

* Statistical analyses of nutrient intakes were made between each dietary period and between both groups using paired and unpaired Student's *t* tests. No significant differences were found.
† Total NSP measured according to Englyst & Cummings (1988)

Table 4. Urinary and serum biochemical variables in sodium-sensitive and sodium-non-sensitive healthy young women during low and high sodium intakes

(Mean values with their standard errors)

	Na-sensitive (*n* 8)				Na-non-sensitive (*n* 8)			
	Low Na		High Na		Low Na		High Na	
	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM
Urine								
Creatinine (Cr) (mmol/l)	16·4	1·5	12·4	1·3	14·6	2·1	14·8	1·7
Na (mmol/mmol Cr)	5·5	0·6	10·5*	1·7	6·1	1·0	11·0*	1·4
Ca (mmol/mmol Cr)	0·15	0·02	0·26*	0·04	0·15	0·02	0·14††	0·03
K (mmol/mmol Cr)	2·7	0·4	4·1	1·0	3·7	0·6	3·6	0·5
Mg (mmol/mmol Cr)	0·31	0·03	0·33	0·02	0·32	0·06	0·31	0·02
Cyclic AMP (mmol/mmol Cr)	0·15	0·03	0·24	0·05	0·23	0·03	0·23	0·05
Pyr (nmol/mmol Cr)	33·4	1·7	36·6	2·5	35·6	1·7	35·1	1·9
Dpyr (nmol/mmol Cr)	8·3	0·5	8·9	0·5	9·1	0·6	9·2	0·7
Serum								
Ca (mmol/l)	2·37	0·09	2·19	0·08	2·21	0·06	2·27	0·08
Mg (mmol/l)	0·81	0·04	0·81	0·05	0·90	0·04	0·82	0·04
B-Alkphase (U/l)	14·4	1·4	16·0	0·9	17·6	1·9	16·7	1·5
Osteocalcin (μg/l)	16·2	2·1	16·4	1·6	16·1	2·4	12·7	1·7

Pyr, pyridinoline; Dpyr, deoxypyridinoline; B-Alkphase, bone-specific alkaline phosphatase.
Mean values were significantly different from those for the low-Na treatment within a sensitivity group, $^{*}P < 0.05$.
Mean value was significantly different from that for the corresponding Na-sensitive group, †† $P < 0.01$.

There was no significant difference in urinary excretion of Na/Cr between the Na-sensitive and Na-non-sensitive groups at either the low- or high-Na intakes.

Urinary excretion of Ca/Cr increased significantly ($P < 0.05$) when Na intake was increased from 80 to 180 mmol/d in the Na-sensitive, but not the Na-non-sensitive group. While there was no significant difference in urinary Ca/Cr levels between the Na-sensitive and non-sensitive groups on the low-Na diet, urinary excretion of Ca/Cr was significantly higher ($P < 0.05$) in the Na-sensitive group compared with the non-sensitive group when both were on the high-Na diet.

There were no significant differences in urinary K/Cr or Mg/Cr excretion or urinary cyclic AMP concentration between the high- and low-Na diets in either the Na-sensitive or non-sensitive groups or between the Na-sensitive and non-sensitive groups for either diet. Similarly, there were no significant differences in serum Ca or Mg concentrations between the low- and high-Na diets in either group or between the two groups for either diet.

There were no significant differences in urinary Pyr/Cr or Dpyr/Cr excretion between the high- and low-Na diets in either the Na-sensitive or non-sensitive group or between the Na-sensitive and non-sensitive groups for either diet.

Similarly, in the case of the biochemical markers of bone formation, there were no significant differences in serum bone-specific alkaline phosphatase or serum osteocalcin levels between the high- and low-Na diets in either the Na-sensitive or non-sensitive group or between the Na-sensitive and non-sensitive group for either diet.

Discussion

It is well established that increasing dietary Na intake within the usual range of dietary intakes increases urinary Ca excretion and that there is a large variability in Na-

induced calciuria between individuals. However, there is considerable uncertainty about whether Na-induced urinary Ca losses result in increased bone resorption. If there is such an effect on bone it would appear to be more likely to be observed in those in whom urinary Ca is most affected by Na. However, there are no studies to date on the influence of dietary Na on bone metabolism in Na-sensitive and Na-non-sensitive subjects.

The average increase of urinary Ca in response to increased dietary Na in the twenty-nine subjects who took part in the screening study (0·66 mmol/100 mmol increase in urinary Na) was similar to results obtained in other studies of similarly-aged premenopausal women which reported increases in urinary Ca of about 0·65 mmol (Breslau *et al.* 1982), 0·70 mmol (Shortt *et al.* 1988) and 0·60 mmol (Itoh & Suyama, 1996) per 100 mmol increase in urinary Na. There was a marked variation in the response between individuals, ranging from no significant response to 4·61 mmol/100 mmol increase in urinary Na intake and a significant response was observed in eight out of the twenty-nine subjects.

This dependence of urinary Ca excretion on urinary Na excretion in the Na-sensitive subjects has been attributed to the existence of linked or common reabsorption pathways for both ions in the convoluted portion of the proximal tubule and thick ascending loop of Henle (Shortt & Flynn, 1990). The reasons for the lack of, or at least much reduced, dependency of urinary Ca excretion on urinary Na excretion in the Na-non-sensitive subjects are unclear.

Urinary Na excretion was approximately twofold greater in subjects consuming the high-Na diet compared with those consuming the low-Na diet. This increase in urinary Na was associated with a 73 % increase in urinary Ca for the Na-sensitive group but urinary Ca was unchanged in the Na-non-sensitive group. The increase in urinary Ca was not influenced by other dietary factors (e.g. Ca, protein, fibre, P or K) which have been reported to influence urinary Ca excretion (Heaney & Recker, 1982; Massey & Wise, 1984) since the intakes of these were similar for the low-Na and high-Na diets.

Increasing Na intake had no effect on the excretion of Pyr or Dpyr in either the Na-sensitive or non-sensitive groups. This is in agreement with Evans *et al.* (1997) who recently reported that urinary Dpyr was unaffected by dietary Na in premenopausal women. Earlier studies in young subjects have reported that higher Na intakes are associated with increased urinary excretion of hydroxyproline (Goulding & Lim, 1983; Goulding *et al.* 1986, Goulding & MacDonald, 1986; Chan *et al.* 1992; Itoh & Suyama, 1996) although Castenmiller *et al.* (1985) found no association of Na-induced calciuria with urinary hydroxyproline excretion. However, the suitability of urinary hydroxyproline as a marker of bone resorption has been questioned due to its lack of specificity and sensitivity and the changes in hydroxyproline excretion may not necessarily reflect changes in bone metabolism, but rather may be due to contributions from other sources, e.g. connective tissues, or from an alteration in the liver catabolism of hydroxyproline (Leitz *et al.* 1997). Additionally, in a number of these studies, dietary hydroxyproline was not controlled and it has been well established that dietary hydroxyproline may affect urinary hydroxyproline excretion (Kivirikko, 1970; Massey & Whiting, 1996).

Na loading also had no significant effect on serum osteocalcin or serum bone-specific alkaline phosphatase, markers of bone formation (Delmas, 1992). This suggests that not only was the resorptive process unaffected by increased Na intake but also that bone formation and thus, bone turnover, were unaffected by varying the Na load.

Increased urinary Ca loss may temporarily depress plasma Ca, leading to enhanced parathyroid hormone (PTH) secretion which helps to restore plasma Ca by increasing bone resorption and, via increased 1,25 dihydroxycholecalciferol, increasing intestinal absorption of Ca (Shortt & Flynn, 1990).

There is evidence that serum PTH is increased in association with Na-induced calciuria (McCarron *et al.* 1981; Breslau *et al.* 1982), although this was not observed in the study of Evans *et al.* (1997). PTH was not measured in the present study but urinary cyclic AMP, a specific marker of PTH action on the kidney, did not change in response to increasing dietary Na intake. It may be that the increase in PTH only occurs over the first few days of Na stress and that PTH levels would have returned to normal values by the twelfth day of the study when blood samples were taken.

Increasing Na intake has been reported to lead to a significant increase in fractional Ca absorption in healthy young adults by an average of 8–25 % (Meyer *et al.* 1976; Breslau *et al.* 1982), although Evans *et al.* (1997) did not observe any effect of increasing dietary Na on Sr absorption (an index of Ca absorption) in premenopausal women. However, the authors of the latter study suggested that the precision of this method may have been too low to detect a change.

The lack of effect of Na on urinary pyridinium crosslinks in the young women in the present study and in the premenopausal women studied by Evans *et al.* (1997) suggests that the Na-induced urinary Ca loss is compensated for by increased Ca absorption rather than increased bone resorption. Thus, the adaptive processes in these subjects appear to be adequate to protect bone, even with the restricted Ca intake (12·5 mmol/d) used in the present study.

However, the capacity for such adaptation may be limited in some individuals, e.g. those with impaired parathyroid function or postmenopausal women with impaired renal function, poor vitamin D status or poor intestinal Ca absorption (Shortt & Flynn, 1990). Impaired adaptation may explain the increased urinary excretion of pyridinium crosslinks in postmenopausal women when Na intake was increased from 50 to 300 mmol/d (Evans *et al.* 1997), although it should be noted that Lietz *et al.* (1997) did not observe this in a similar study using a lower Na load (60–170 mmol/d). Impaired adaptation was also suggested in the study of Breslau *et al.* (1985) who found no increase in intestinal Ca absorption in seven osteoporotic postmenopausal women when Na intake was increased from 10 to 250 mmol/d while dietary Ca was maintained at 10 mmol/d. Evans *et al.* (1997) suggested that maladaptation to high Na intake may contribute to the development of postmenopausal osteoporosis.

In conclusion, the present study shows that increasing Na intake from 80 to 180 mmol/d significantly increases urinary Ca excretion in some individuals (Na-sensitive) but not others (Na-non-sensitive). However, it appears that in these healthy young women this Na-induced calciuria does not result in increased bone resorption or turnover and that adaptation of dietary Ca absorption may compensate for the increased urinary Ca loss.

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