



## Incidence of osteoporosis in vegetarians and omnivores<sup>1, 2</sup>

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This investigation was initiated by the hypothesis proposed by Wachman and Bernstein (1) that "bone dissolution is considered as a possible mechanism to buffer the fixed acid load imposed by the ingestion of an 'acid ash' diet in man." If this hypothesis is feasible, one would expect to observe a greater degree of bone dissolution in a diet that contains meat (a primary source of acid ash) than in a vegetarian diet.

Various studies (2, 3) have shown that there is an increased bone loss with age; this loss begins at approximately age 35 to 45 in women and approximately 45 to 65 in men. The rate of loss is also greater in females than in males.

The diagnosis of osteoporosis by subjective study of X-rays is inaccurate unless the changes are gross. As a result, various quantitative methods have been devised for the measurement of bone density, e.g., X-ray and gamma-ray densitometry. The hands are usually examined, as this is more convenient for the subject and there is less soft tissue to affect density readings. West and Reed (4), however, have found the best results by examination of the femur. Another method of assessing bone density is by measuring the cortical thickness and the total diameter of the 2nd metacarpal. The result is expressed as cortical thickness to total thickness ratio because this value is a function of bone density rather than bone mass and has a much smaller standard deviation (5, 6).

### Materials and methods

A group of twenty-five British vegetarians (ovo-lacto vegetarians), consisting of eight males and

seventeen females with an age range of 53 to 79 years, was studied. A blood sample was taken for laboratory investigation.

In this short preliminary investigation, it was decided to use a simple method of testing bone density, particularly as the more complicated apparatus was not available and patients came intermittently from various parts of the country.

The right hand was examined in all instances except in two patients who were left-handed. Kodak cassettes with high resolution screens and rapid process films were used. The X-ray factors were 45 kv, 50 to 70 ma, at 58 inches tube-focus distance to avoid as much magnification as possible. A graduated aluminum step-wedge (1 to 8 mm) was placed on each film to ensure uniformity of density. The processing of all X-rays was by a 90-sec automatic apparatus.

As the 3rd finger was in the center of the X-ray film, it was decided to determine the density of the center of the third metacarpal medulla and the proximal phalanx using a Baldwin Radiological Densitometer. The centers of these bones were accurately measured and great care was taken to place this area in the center of the densitometer aperture. Because of the age of some of the patients, there was not a sufficiently clear distinction between the medulla and cortex and it was felt that cortical measurements would be inaccurate. All the densitometer readings were determined on the same day to ensure uniformity and accuracy.

The hemoglobin and white cell count were determined on a Coulter Model S, the sedimentation rate by the method of Westergren, and the serum concentrations of urea, cholesterol, calcium, phosphate, and proteins were determined by standard automated laboratory techniques. The serum B<sub>12</sub> was determined by the *Lactobacillus leichmannii*

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<sup>2</sup> Supported by a grant from the South West Metropolitan Regional Hospital Board.

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method (7) and the serum folate by the method of Chanarin (8).

A control group of 25 omnivores, matched for age ( $\pm 3$  years) and sex, were also studied (Table 1).

## Results

In Table 2, the results of the radiological and laboratory investigations are given as the mean ( $\pm$ SD) of the two separate groups. The mean of the serum folate and proteins in the control group were determined on groups of 21 and 24, respectively; in all other cases, the means are for groups of 25.

The significance was determined by applying a *t* test on the paired observations and the level of significance was taken as  $P < 0.05$ .

Table 2 shows that the density of the bones that were measured was significantly greater in the vegetarians than in the omnivores, whereas the hemoglobin, urea, calcium, vitamin B<sub>12</sub>, and total proteins were significantly lower. In all the other findings there was no significant difference.

Table 3 shows the relationship between bone density and age. The density of the bone is shown as a mean ( $\pm$ SD) for each of the three age groups: 50 to 59, 60 to 69, and 70 to 79 years. The results are given for the density of both the proximal phalanx of the 3rd finger and for the 3rd metacarpal. In all age groups, the bone density of the vegetarians was greater than that of the controls. The mean bone densities of the 70- to 79-year age groups of the vegetarians was greater than the densities of the 50- to 59-year age group of the omnivores.

## Discussion

The vegetarians included in this study had bone densities significantly greater than those of individually matched omnivores. Because the vegetarians were matched for age and sex with the omnivores, any variation due to these two criteria would tend to be removed. These results support the hypothesis of Wachman and Bernstein (1) that bone dis-

TABLE 1

Controls			Sex	Vegetarians			
Weight, kg	Height, cm	Age, years		Age, years	Height, cm	Weight, kg	Years as vegetarian
73.2	175	53	M	55	170	76.1	35
59.8		57	M	56	165	57.3	42
63.9	179	58	M	59	180	70.0	35
75.4	176	61	M	64	168	65.2	30
83.0		65	M	65	175	69.1	20
71.4		67	M	65	172.5	53.7	52
97.3		68	M	71	174	61.9	59
		81	M	83	176	73.3	30+
66.4	167	55	F	53	140.5	60.6	53
66.2	159	56	F	54	172	76.0	30
64.7	166	57	F	55	153	63.5	35
51.2	156	58	F	57	148.5	51.2	12
60.0	156	58	F	57	153.5	65.9	39
65.2	161.5	61	F	58	150.5	70.8	20
64.9	155	61	F	61	150.5	47.8	13
63.0	162	63	F	62	163	45.0	10
63.5	162.5	64	F	63	142.5	41.9	35
		65	F	68	169.5	56.0	68
68.0		68	F	69	162	49.6	17
53.5	149	73	F	71	147	55.8	33
73.0	160	73	F	72	152	54.0	12
70.6		75	F	74	160	48.5	21
67.5	154	78	F	77	150.5	52.0	77
73.2	163	78	F	77	161	44.8	54
61.5		79	F	79	154	62.9	64

TABLE 2

Investigation	Vegetarians		Controls		Significance
	Mean	SD	Mean	SD	
Density of proximal phalanx of 3rd finger	1.37	0.31	0.88	0.24	$P < 0.001$
Density of 3rd metacarpal	1.06	0.25	0.64	0.17	$P < 0.001$
Hb, g/100 ml	13.1	1.0	14.5	1.3	$P < 0.001$
WBC, /mm <sup>3</sup>	6,300	1,800	7,300	3,100	$0.1 < P < 0.2$
ESR (Westergren), mm/1 hr	20	18	15	16	$0.2 < P < 0.3$
Urea, mg/100 ml	32	7	37	10	$P < 0.05$
Cholesterol, mg/100 ml	245	64	246	57	$0.95 < P < 0.975$
Calcium, mg/100 ml	9.4	0.7	10.0	0.4	$P < 0.005$
Phosphate (as P), mg/100 ml	3.5	0.5	3.6	0.6	$0.5 < P < 0.6$
Vitamin B <sub>12</sub> , pg/ml	261	112	411	207	$P < 0.01$
Folate, ng/ml	11.8	6.6	7.9 (21)	4.7	$0.05 < P < 0.1$
Total proteins, g/100 ml	7.3	0.4	7.5 (24)	0.5	$P < 0.05$

Except where figures are shown in parentheses, all sample sizes are 25.

TABLE 3

Age groups, years	Density of proximal phalanx of 3rd finger		Density of 3rd metacarpal	
	Vegetarians	Controls	Vegetarians	Controls
	Mean $\pm$ SD	Mean $\pm$ SD	Mean $\pm$ SD	Mean $\pm$ SD
50-59	1.50 $\pm$ 0.22 (9)	1.02 $\pm$ 0.19 (7)	1.14 $\pm$ 0.18 (9)	0.71 $\pm$ 0.17 (7)
60-69	1.27 $\pm$ 0.27 (8)	0.88 $\pm$ 0.27 (10)	1.01 $\pm$ 0.19 (8)	0.68 $\pm$ 0.19 (10)
70-79	1.32 $\pm$ 0.40 (8)	0.73 $\pm$ 0.17 (7)	1.03 $\pm$ 0.36 (7)	0.55 $\pm$ 0.14 (7)

Figures in parentheses denote the number of subjects in that group.

solution is greater in individuals who utilize a diet high in acid ash, i.e., omnivores, whether in fact this difference is due to acid ash or any other dietary differences, e.g., calcium intake, has yet to be determined. The results also suggest that vegetarians are less prone to osteoporosis than omnivores.

When bone density was related to age, both sets of measurements showed that the bone density of the omnivores decreased with age; this was also seen in the vegetarian group but to a lesser degree. No further decrease in bone density appeared to take place in the vegetarians who were approximately 69 years old, whereas it continued to decrease in the omnivore group. These results suggest that there is less likelihood of vegetarians developing osteoporosis in old age.

The serum calcium in vegetarians was significantly lower than it was in the controls, but both mean values were within the normal

range (8.5 to 10.5 mg/100 ml). There was, however, no significant difference in serum phosphate concentrations (normal range 2.5 to 4.8 mg P/100 ml). The dietary intake of calcium has been shown to be greater in vegetarians than in omnivores (9); therefore, the lower serum level in vegetarians is unlikely to be due to a dietary inadequacy. If the hypothesis of Wachman and Bernstein is true, then there will be greater dissolution of bones in omnivores, and this may give rise to a higher serum calcium level. The serum phosphate was no higher in the omnivores, as might have been expected if a greater degree of bone dissolution was occurring. This may be accounted for, however, by the phosphate being removed during its buffering action of the acid ash.

The serum concentration of vitamin B<sub>12</sub> was significantly lower in vegetarians than in the controls; this has been shown in other

studies on vegetarians and vegans (10, 11). The reason for this low level is the low dietary intake in these minority groups. There was no significant difference in the serum folate, which has been found to be higher in vegans (9, 12) due to their high dietary intake of green vegetables. Nine omnivores had folate concentrations below the normal values (6 to 20 ng/ml), whereas only two vegetarians had values below normal. The results of the vitamin B<sub>12</sub> concentrations showed that only one omnivore had a serum vitamin B<sub>12</sub> value below 150 pg/ml, whereas three vegetarians had concentrations below this level (normal range 150 to 900 pg/ml).

The serum urea levels in vegetarians were significantly lower than those of the omnivores, but both mean values were within the normal range (13 to 44 mg/100 ml). A similar finding has been demonstrated in vegans (12). This lower blood urea may be a reflection on the lower dietary intake of protein in vegetarians (9) and may also account for the significantly lower serum total protein levels.

### Summary

A study of the bone density of vegetarians compared with age- and sex-matched omnivore controls was carried out. A significant difference was noted in vegetarians, which suggests that they are less prone to osteoporosis than omnivores. Other biochemical differences were also found. ☞

We are grateful to Dr. B. W. Meade for the biochemical investigations, Dr. L. Bernstock for the serum folate estimations, and Dr. J. W. T. Dickerson for his kind advice. Thanks are also due to Mr.

Greenslade for the loan of the densitometer, Miss M. Bean for taking the radiographs, and Mrs. A. Harper for her help with the measurements of the hands. We are also indebted to Mrs. J. Stopford for secretarial assistance.

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