The Relation Between Calcium Intake and Roentgenologic Osteoporosis

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OSTEOPOROSIS is a clinical disorder characterized by a reduction in bone mass without any known change in its chemical composition. The disorder may be localized or generalized and it may present as a disease in its own right or be associated with some other clinical disorder, particularly of the endocrine system. It is, therefore, appropriate to classify generalized osteoporosis into primary and secondary types[1]; this paper deals only with the primary type, i.e., with osteoporosis not associated with any known predisposing condition.

It has been orthodox teaching for about twenty years that osteoporosis is a disorder of the protein rather than the mineral component of bone.[2] This hypothesis, introduced in 1941,[3] rests on the assumption that vitamin D deficiency and calcium deficiency produce the same clinical syndrome, namely, osteomalacia. For reasons explained elsewhere,[4] this assumption is probably incorrect inasmuch as calcium deficiency in animals usually leads to a diminution in bone mass (i.e., osteoporosis) rather than a diminution in bone ash (i.e., osteomalacia). The explanation for this is probably that negative calcium balance produces resorption of whole bone and that a reduction in bone mineral content only occurs when there is insufficient calcification of new osteoid.

We have presented elsewhere some of the evidence indicating that clinical osteoporosis in man could be due to prolonged negative calcium balance.[1,4–7] In the present paper we have assembled all the diet histories and bone roentgenograms collected by us from 1957 through 1960 and have tested the over-all relationship between dietary intake and the roentgenologic state of the skeleton.

METHODS

Diet histories were obtained by the dietitians of the Western Infirmary. The subjects were interviewed individually for about forty-five minutes with a view to obtaining a general picture of their dietary habits over the previous five years. Details were recorded of typical weekday and Sunday meals, particular attention being paid to calcium-containing foods such as milk, cheese and bread (which in the United Kingdom is fortified with calcium carbonate). The subjects were frequently asked to bring to the hospital a typical slice of bread for weighing and given a liquid measure to obtain a more precise estimate of their milk intake.

The standard roentgenograms were comprised of a lateral view of the lumbar spine and films of the hands and femur (posteroanterior view). These roentgenograms were measured by the method of Barnett and Nordin[8] which involves determination of cortical thickness and of vertebral biconcavity. Cortical thickness should be more than 43 per cent of the total diameter of the second metacarpal at its midpoint and more than 45 per cent of the total diameter of the femur at the thickest point of the cortex. The total peripheral bone score is, therefore, more than 88/200 in normal subjects, and a figure of 88 or less is regarded as abnormal and is termed peripheral osteoporosis. The vertical height of the best-centered lumbar vertebra should be not less than 81 per cent of its height anteriorly and a score of 80 per cent or less is termed spinal osteoporosis. The total "score" should, therefore, be not less than 169/300 in normal subjects.

The 231 subjects in this report include all the patients seen in the years 1957 through 1960 for whom diet histories and roentgenograms were

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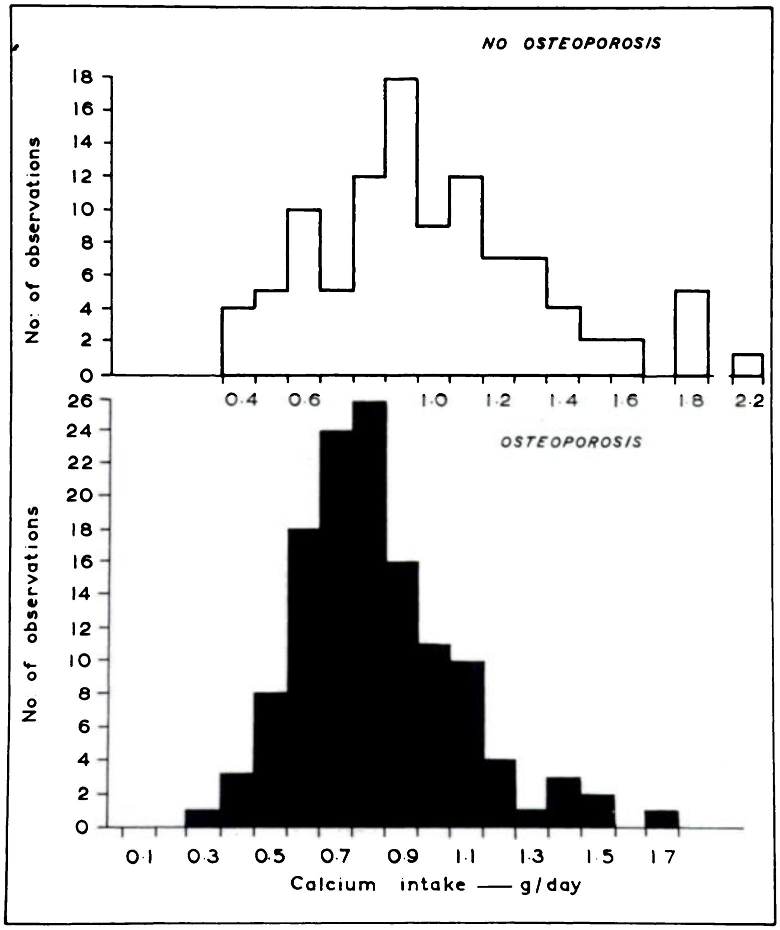

FIG. 1. Frequency distribution of calcium intake in subjects with and without osteoporosis.

available with the exception of those with steatorrhea. Included are patients who were referred to the Bone Clinic with backache as well as hospital inpatients and outpatients who were chosen to serve as control subjects for the roentgenographic and dietary surveys.[5,8]

TABLE I
Mean Calcium Intakes and Standard Errors (S.E.) in Patients with and Without Osteoporosis

Group	No.	Mean Weight (kg.)	Calcium Intake (mg.)		p
			Mean	S.E.	
No osteoporosis...	103	58	930	34	<0.01
Osteoporosis	128	57	776	22	

The control subjects chosen were of comparable age and sex. In both series, therefore, the majority of subjects were in the fifth, sixth, seventh or eighth decades. Seventeen control subjects were less than forty years old and one was over eighty; six patients with osteoporosis were under forty years of age and three were over eighty.

RESULTS

The frequency distributions of calcium intake in the subjects with and without osteoporosis are shown separately in Figure 1, and the means and standard errors are given in Table I. The mean calcium intake of the "normal" subjects was 930 mg. per day and that of the patients with osteoporosis 776 mg. per day. The mean body weight of the two groups was virtually the same and the difference in calcium intake is highly significant whether con-

TABLE II
Mean Calcium Intakes According to Sex and Diagnosis

Group	No.	Mean Weight (kg.)	Calcium Intake (mg.)		p
			Mean	S.E.	
Men					
"Normal"...	29	62	1,103	62	
Osteoporosis.	27	63	876	45	<0.01
Women					
"Normal"...	74	57	862	38	
Osteoporosis.	101	55	749	24	<0.02

sidered in absolute terms or in relation to body weight. Table II shows the same data analyzed separately for males and females. The difference between the calcium intakes of the "normal" men and those with osteoporosis was greater than the corresponding difference among the women, but in each sex it was statistically significant. The table also shows that the calcium intake of the "normal" men was significantly greater than that of the "normal" women.

The relation between calcium intake and roentgenologic score is shown in Figure 2. The horizontal line corresponds to the score of 168 which represents the highest total abnormal score. (It must be remembered, however, that a score over 168 sometimes conceals an abnormal spinal or peripheral score.[8]) The figure shows that there are only six patients with x-ray scores below 169 and calcium intakes over 1.0 gm. daily (Table III). Subjects with x-ray scores over 168, on the other hand, are more or less uniformly distributed over the whole range of dietary calcium intakes.

The relation between calcium intake and the peripheral and spinal scores is also shown separately in Table III. In each group, there are relatively few abnormal patients with daily calcium intakes of 1.0 gm. or more. The most convincing relationship between dietary calcium and osteoporosis is seen, however, when

TABLE III
Classification of Subjects According to Calcium Intake and Type of Osteoporosis

Type of Osteoporosis	Calcium Intake	
	<1 gm.	1 gm. and over.
Spine		
Normal....................	94	45
Abnormal..................	76	16
Peripheral		
Normal....................	103	53
Abnormal..................	67	8
Total score		
Normal....................	109	55
Abnormal..................	61	6
Normal bones.................	63	40
All types of osteoporosis........	107	21
Totals......................	170	61

all types of osteoporosis are considered together, as shown also in Table III, which corresponds with Figure 1. There are 107 cases of osteoporosis among 170 subjects whose daily calcium intakes are less than 1.0 gm. and only twenty-one cases among sixty-one subjects whose intakes exceed 1.0 gm. daily.

Since the "normal" subjects in this series are a heterogenous group, consisting partly of chosen control subjects and partly of patients with backache investigated for osteoporosis with negative result, the "normal" data have been broken down further in Table IV to distinguish between these two categories. The table shows that the mean calcium intake of the true control subjects was 1,065

TABLE IV
Mean Calcium Intakes in Control and Other "Normal" Subjects

Subjects	No.	Mean Weight (kg.)	Calcium Intake (mg.)		p
			Mean	S.E.	
Control....	41	62	1,065	53	<0.01
Other "normal".....	62	61	870	43	

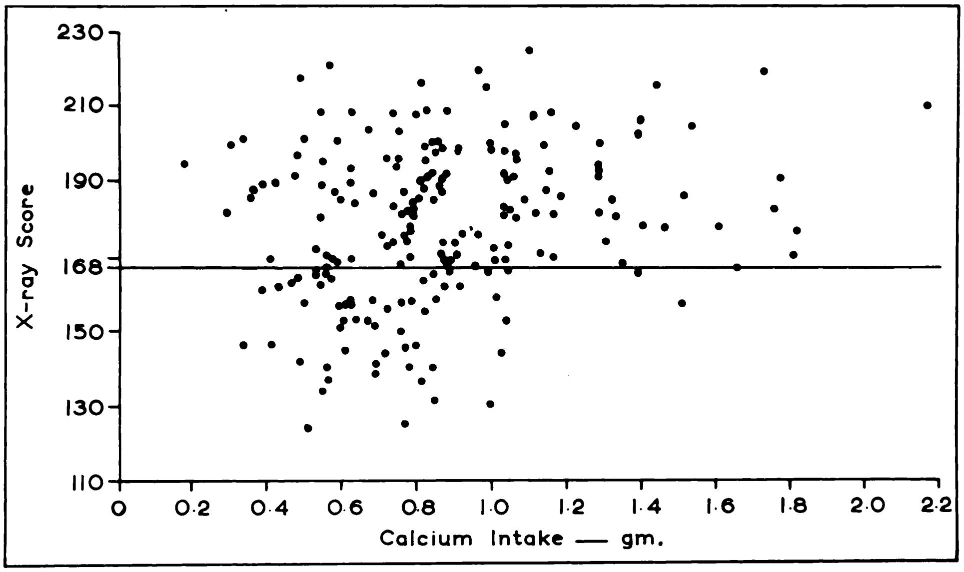

FIG. 2. Relation between calcium intake and x-ray "scores." Values below the horizontal line represent abnormal scores.

mg. per day, whereas the mean intake of the remainder, mostly patients with backache suspected of osteoporosis, was 870 mg. per day. The difference is highly significant.

The urinary calcium:creatinine ratio (Ca: Cr)[9] was measured in eighty-eight of the "normal" subjects and in 121 of those with osteoporosis. The data are shown in Figure 3 and Table v. The mean Ca:Cr ratio was 0.21 in both groups, but Figure 3 shows that whereas the distribution could perhaps be regarded as Gaussian in the "normal" subjects it is possibly bimodal in those with osteoporosis, with peaks at about 0.1 and 0.25. It must be remembered that the "normal" subjects probably include some subjects with mild osteoporosis (as already explained) and that our earlier control series showed a true Gaussian distribution.[9]

The protein intakes are shown in Table VI. The protein intake of the "normal" subjects was significantly higher than that of the patients with osteoporosis, but seemed quite adequate in both groups.

TABLE V
Mean Ca:Cr in Subjects with and Without Osteoporosis

Group	No.	Mean Ca:Cr
No osteoporosis	88	0.21
Osteoporosis	121	0.21

COMMENTS

We have confirmed that there is a small but significant difference between the calcium intakes of patients with and without osteoporosis, the mean intake of the latter being below the recommended requirement.[10,11] The distribution of the data is such as to suggest that osteoporosis does not develop in the presence of a high calcium intake, but that if calcium intake is low, osteoporosis may or may not develop, presumably depending upon whether adaptation to the intake does or does not occur. The calcium intake of the men in this series was significantly higher than that of the women, and this difference was greater than could be accounted for by the difference in their mean body weights. It is tempting to suggest that this difference between the calcium intakes of men and women might explain the sex difference in the incidence of osteoporosis.

Although the difference between the calcium intakes of the "normal" subjects and those with osteoporosis is highly significant, it is relatively small in absolute terms, par-

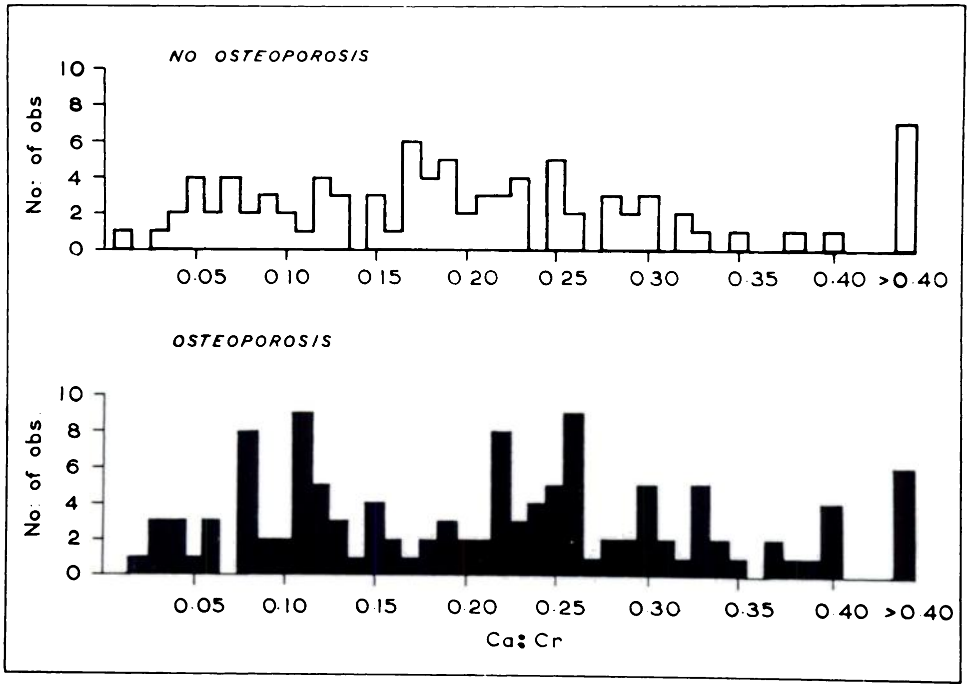

FIG. 3. Frequency distribution of Ca:Cr in subjects with and without osteoporosis.

ticularly among the women, possibly because the mean intake of our "normal" subjects (930 mg. or 16 mg. per kg.) is appreciably less than the national average intake in the United Kingdom (about 1,200 mg. per day).[5] It is possible that this is the result of our x-ray procedure for the diagnosis of osteoporosis. As we have pointed out elsewhere,[8] our procedure tends to "under-diagnose" osteoporosis; it does not yield false positive results but it certainly produces false negative results. Thus, although it can be stated emphatically that all our patients with osteoporosis are suffering from osteoporosis, we are aware that many of our "normal" subjects may also be suffering from mild degrees of osteoporosis insufficient to produce thinning of cortical bone or biconcavity of vertebral bodies. It is, therefore, probable that the mean calcium intake of our "normal" subjects is lower than it would be if they were all truly normal; this suggestion is strongly supported by the observation that the mean intake of the true control subjects was significantly higher than that of the other "normal" subjects, most of whom presented with backache.

Although the protein intake of the patients with osteoporosis was also significantly less than that of the "normal" subjects, it seems unlikely that this could have contributed to their disease. In the first place, the mean protein intake of the patients with osteoporosis (59 gm. per day) is adequate by any known standard. Moreover, we have shown elsewhere[7] that patients with osteoporosis are as able as normal subjects to reduce their urinary excretion of nitrogen on a low protein intake and so to remain in nitrogen balance. Although we have not yet seen any patient with osteoporosis in negative nitrogen balance on

TABLE VI

Mean Protein Intakes of Subjects with and Without Osteoporosis

Group	No.	Protein Intake (gm.)		p
		Mean	S.E.	
No osteoporosis...	103	67	1.8	
Osteoporosis.....	128	59	1.6	<0.01

the home intake of protein, we have frequently observed patients in negative calcium balance on their home diets apparently owing to a failure to regulate the urinary excretion of calcium in accordance with their intake. For these and other reasons it seems that the low calcium intake, rather than the low protein intake, of patients with osteoporosis is more likely to be the cause of their disease.

The validity of these observations and their relevance to the pathogenesis of osteoporosis depend of course upon their accuracy. It is frequently said that dietary histories are so imprecise as to be of little value. However, it has been shown[12] that there is a good correlation between the dietary intake calculated from a diet history and that based on a weekly weighed food survey, and our experience is in accordance with these findings. It is also our impression that the dietary habits of most people are relatively constant and that in the majority of subjects a careful diet history reflects the dietary habits of that individual extending back over many years.

Calcium intake is only one factor in determining calcium balance, the other two being absorption and excretion. The present study reports no observations on calcium absorption, but we have shown elsewhere that the calcium absorption of patients with osteoporosis as a group does not differ significantly from that of normal subjects if patients with steatorrhea are excluded.[13,14] As for calcium excretion, the mean Ca:Cr ratio of the patients with osteoporosis reported in this series is the same as that of the "normal" subjects, although the mean calcium intake of the former is significantly lower. There is, however, a suggestion that the distribution of Ca:Cr values in those with osteoporosis is biphasic, whereas the distribution in the "normal" subjects appears to be Gaussian. It might be inferred that in some patients with osteoporosis the reduction in the urinary excretion of calcium in response to a low calcium intake has been more successful than in others.

SUMMARY

Diet histories and x-ray scores are reported in 128 cases of osteoporosis and 103 "normal" subjects. The mean calcium and protein intakes of the "normal" subjects were significantly higher than those of the patients with osteoporosis. However, the mean calcium excretion was the same in the two groups.

Virtually no subjects on high calcium intakes were found to have osteoporosis, but low calcium intakes were frequently associated with apparently normal bones. Many of these latter subjects, however, complained of backache.

The present study sheds no light upon the role of age in the pathogenesis of osteoporosis except insofar as the duration of negative calcium balance would be a factor in determining the onset of clinical manifestations. Thus, a negative calcium balance of 100 mg. per day would involve the removal of 36.5 gm. of calcium from the skeleton every year, with a corresponding destruction of whole bone. If clinical osteoporosis involves the destruction of about 30 per cent of the skeleton then it would take about ten years for osteoporosis to develop at this rate of negative balance. A negative balance of 50 mg. per day could last for twenty years before it caused a clinical disease. In these circumstances, it is inevitable that the disease becomes more frequent with advancing age and should, in fact, appear to be a manifestation of the aging process.

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