OSTEOPOROTIC HIP FRACTURES
An epidemiological, radiological and clinical study with special reference to bone mineral measurements

by
Esko M. Alhava

Kuopio 1974
From the Department of Surgery, University Central Hospital, Kuopio

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ACADEMIC DISSERTATION
to be publicly discussed, by permission of the Medical Faculty of the University of Kuopio, at the Town Hall of Kuopio on May 25th, 1974, at 12 o'clock noon

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LIST OF PUBLICATIONS

This work is based on the following papers referred to as I--V in the text.


IV  Alhava EM: Correlations of histological, radiological and gamma transmission methods in evaluating osteoporosis of patients with fractured hips. Ann Clin Res

INTRODUCTION

Fractures of the upper end of the femur are of great clinical importance, because they are common and keep patients in hospital for a long time. The number of hospital admissions in Finland in 1968 for fractures of the upper femur was 2,178, with an average hospital stay of 42.3 days. These hospital admissions accounted for 4.7 per cent of all hospital admissions and for 10.1 per cent of all treatment days due to accidents. These figures do not include admissions to homes for the elderly and comparable social institutions to which some of these patients were referred after primary therapy (18). Fractures of the upper end of the femur thus constitute a fairly heavy burden on the whole hospital system. They are the commonest cause of traumatic death among persons aged over 75 (21).

Cooper (8) stated in 1824 that age was a factor in the genesis of bone changes that resulted in fractures of the hip. Subsequent epidemiological studies have pointed in the same direction (3,4,5,19). Urist (20) reported that osteoporosis was more common in patients with fracture of the upper femur than in coeval healthy persons. Vose et al. (25) observed that less force was needed to fracture osteoporotic bones than healthy bones. Three factors, trauma, illness and non-specific fragility of bones in association with ageing, were stated by Alffram (1) in his epidemiological study to contribute to hip fractures.
Most of the injuries that result in fracture of the upper femur are of moderate severity. A clear decrease in the incidence of fractures caused by severe trauma and a distinct increase in the incidence of less violent fractures can be seen in the older age groups. In addition to trauma local factors at the fracture site and more generalised diseases which lead to fragility of the whole skeleton may be important in the aetiology of fractures.

Osteoporosis is caused by several different factors. It can be defined as a decreasing amount of bone mass per total bone volume in which increased bone resorption is the principal mechanism (22). Osteomalacia, which means softening of the bones, is associated with vitamin D and calcium deficiencies and/or disturbed vitamin D metabolism. It may contribute to fractures of the upper femur (7). Bauer et al. (3) introduced the term "osteopenia" to include all the bone mineral changes caused by osteoporosis, osteomalacia and hyperparathyroidism.

Bone mineral content has been measured in vitro by chemical and physical methods which are difficult to apply in vivo. Most methods of measuring bone mineral content in vivo have been radiological. But a new method which is based on gamma ray transmission (6) is more accurate and reliable (16). Ultrasound has also been used with less success (14, 15).

The term bone density is widely used in radiological literature. Physically, density is the ratio of mass to volume.
However, as film density is a term generally employed in photography, the use of the term "bone density" sometimes causes confusion. Film density in photography is darkening of the film which can be measured densitometrically. It has therefore been suggested that the term "mineral content" of bone be used in radiology (9).

The mineral content can be denoted as g/cm of bone or g/volume unit of bone in the gamma transmission method. Karjalaninen (10) uses the terms "mineral content" for the former and "mineral density" for the latter.

The present consensus is that the radiographs alone do not provide enough evidence on which to make a diagnosis of osteoporosis or any other change in bone mineral content. As bone mineral is also decreased in osteomalacia, a diagnosis of osteoporosis should not be made without histological study (9), laboratory investigations and possibly also mineral determinations.
The purpose of this work was:

1. to study the incidence of osteoporosis in Finland by an epidemiological analysis of fractures of the upper femur and to compare the incidence of osteoporosis in Finland with that in other populations.

2. to determine the bone mineral content (g/cm) and density (g/cm^3) in healthy people using the Am-241 gamma transmission method.

3. to study the bones of patients with osteoporotic fractures and to see if the gamma transmission method could detect osteoporotic patients with a high risk of fractures in order to give them prophylactic treatment.

4. to compare different radiological and histological methods in measuring osteoporosis.

5. to see what diseases contribute to bone fragility in patients with fractured hips.
MATERIAL AND METHODS

In paper I we considered all (1,442) upper femoral fractures recorded in Finland in 1968 in the National Board of Health statistics of patients admitted to hospitals. The hospital records of patients admitted to the Central Hospital of Kuopio in 1968 were searched to find out how many of the fractures reported to National Board of Health were caused by weakness of bones. The standard population comprised an adjusted quarter of a million Finnish population and comparisons were made with other populations.

In paper II we studied 124 healthy people of both sexes from 20 to 87 years. The mineral content (g/cm) and density (g/cm³) of the forearm bones were measured using a modification (10) of the gamma transmission method (6). The source of the radiation was a 45 mCi Am-241 radionuclide, with gamma energy of 60 keV.

In paper III we examined 63 women and 17 men with fractured hips who had been admitted to the University Central Hospital of Kuopio. They were chosen because the descriptions of their accidents suggested that their fractures had been associated with weakness of their bones. The mineral content and density of the distal radius was measured using Am-241 gamma transmission. 124 people with healthy bones (II) were used as controls.
In paper IV osteoporosis was assessed in a series of 104 patients with fractured femurs by measuring the mean trabecular width of the iliac crest histologically and, on X-rays, measuring the cortical index of the femoral diaphysis (23,24) and scoring the femoral trabecular pattern (17). The results were compared with the mineral density of the radial metaphysis measured by Am-241 gamma transmission.

In paper V there were 81 women and 23 men with hip fractures treated at the University Central Hospital of Kuopio in 1970—1972. Iliac crest biopsies were performed to detect osteomalacia and other pathological conditions of bone. Laboratory investigations included serum calcium, serum phosphorus, alkaline phosphatase, 24-hour urinary excretion of calcium, 4-hour calcium retention test and 24-hour urinary excretion of hydroxyproline. X-rays were taken of the chest, the thoracic and lumbar spines, the pelvis and any painful bones. The diagnosis of osteomalacia required at least three of the following: a lowered serum calcium and phosphorus product, raised serum alkaline phosphatase, a histopathological picture of osteomala- cia, typical radiographic appearances and a response to vitamin D administration whereby the biochemical serum changes of osteomalacia returned to normal, clinical symptoms disappeared and the radiographic changes improved.
SUMMARY OF THE RESULTS

I

There were 1,442 fractures of the upper end of the femur in Finland in 1968. 1,025 were in women and 417 in men. Fractures became more frequent with advancing age. The increase in incidence was considerably greater for women than men. The fracture occurred three times more often in Finnish women than in men. The fractures were associated with severe trauma more commonly in younger people, particularly in men.

The fracture frequency in women is greatest in Malmö (Sweden) and Jerusalem according to the reports from those two cities. The frequency rapidly increases in Finland after the age of 45 and is distinctly higher than in Hong Kong. The male fracture frequency grows considerably more slowly and the Hong Kong, Jerusalem, Malmö and Finnish series are much the same in this respect. The frequency of fractures in female and male South African Bantus is very low and differs completely from that for other populations.

II

In healthy people both the mineral content (g/cm) and density (g/cm³) decreased with increasing age after reaching a certain maximum. The bone mineral density was greater in men than in women. The
mineral content was greater in the stronger than in the weaker limb, although the difference was not significant at every measuring point. In contrast, the mineral density was either significantly greater in the weaker limb or no significant difference could be seen.

III The female mean mineral density (g/cm$^3$) was statistically significantly ($p<0.001$) smaller in the hip fracture patients than in the controls, and the same was true of the male mean mineral density ($p<0.05$). On the other hand, the mineral content (g/cm) did not differ statistically significantly from the controls in either sex.

IV Statistical analysis of the parameters employed in measuring osteoporosis showed a significant correlation ($p<0.01$) between the mean trabecular width in the bone at the iliac crest and the mineral density of the radial metaphysis in female patients and a highly significant correlation ($p<0.001$) in male patients. In contrast, there was no significant correlation between the femoral cortical index and mineral density in either sex. The same result was obtained comparing the femoral trabecular pattern and mineral density in both sexes.
In the hip fracture series 44 per cent of the women and 39 per cent of the men had one or more diseases in which the fragility of the bones is increased. All patients under 50 had such a disease. Osteomalacia was diagnosed in six of 81 women but not in a single man.
GENERAL DISCUSSION

The reduction of bone mass in proportion to bone volume is generally accepted as an inevitable concomitant of ageing. This decrease in mineral content and density of bone, leads possibly, in turn, to osteoporotic fractures. Osteoporosis, which is defined as reduction in bone mass in relation to total bone volume, has many causes but occurs primarily through increased bone resorption (22). When osteoporosis is pathological and when it is within normal limits for the age of the patient is still an open question. But when it causes distress, such as back pain, or when minor trauma results in a fracture, it must be regarded as a disease, and any fracture as pathological.

All cases of hip fracture in Finland in 1968 were included in the epidemiological part of the present study (I). This therefore included also fractures caused by severe trauma in which osteoporosis played no part. However, it has been reported (1) that the incidence of fractures due to severe trauma diminishes with age, whereas that of fractures of less violent origin increases. The rise in incidence in hip fractures associated with ageing may thus reflect the development of senile osteoporosis. Fractures selected according to the same criteria were the basis for the comparisons between different populations and the parallel trends of the results suggest similar aetiological factors. Research workers are fairly unanimous that the mineral content of bones reaches a maximum
between the ages of 25 and 30 years and then progressively decreases. Cancellous bone decreases to approximately half its maximal level during the last years of life. One might expect a higher mineral content at the age of 25--30 to be associated with a later onset of overt senile osteoporosis. Nutritional deficiencies during growth may thus lead to earlier osteoporotic changes in old age. Epidemiological studies of physical activity (11) emphasise that as people age there is good correlation between decreasing physical activity and bone mineral loss. The incidence of upper femoral fractures is greater in countries with a high standard of living than in under-developed countries, which might be due to a decrease in physical activity associated with rising standards of living. Athletes have higher bone mineral densities than "ordinary " people (13), and in astronauts the bone mineral content falls in relation to the duration of weightlessness and inactivity (12) though this has so far been on a much shorter time scale. However, once senile osteoporosis has begun it is probably impossible to reverse it by physical activity, though its progression may obviously be arrested (11).

The correlation between advancing age and decreasing bone mineral content was clearly shown in the paper II in which the mineral content and density of people with healthy bones were measured. This population had a healthier mineral situation than the general population, but in adults exception for a few conditions such as fluorosis, most diseases are associated
with a decrease in bone mineral. As a decrease in bone mineral content leads to an increased risk of fractures, it is rational to use the healthiest possible bones as the normal to aim at when trying to prevent fractures. The patients with fractured hips had a lower bone mineral density than healthy subjects (III), but young diabetics and rheumatics had a distinctly low bone mineral density especially in the presence of the osteomalacia (V). None of the fracture patients had any disease known to be associated with increased bone mineral content. I conclude from IV that the determination of the mineral density of peripheral cancellous bone by gamma transmission is a good way of detecting osteoporosis in population surveys. An osteoporotic fracture in an adult presupposes a decrease in mineral density (g/cm³) which may be independent of age.
1,442 fractures of the upper end of the femur in Finland in 1968 were analysed to obtain an index of senile osteoporosis. The bone mineral content and density of 124 people with healthy bones were measured by Am-241 gamma transmission. The same measurements were made on 80 hip fracture patients whose fracture was attributed to abnormal bone fragility. 104 patients with hip fractures were analysed to compare the various methods of measuring osteoporosis and to detect diseases contributing to bone rarefaction.

The following results were obtained:

1. The increasing incidence of hip fractures with age was associated with senile osteoporosis. Hip fracture was three times more common in Finnish women than men. Comparisons between different nationalities shows that the incidence of hip fractures rises as the standard of living rises.

2. After reaching a maximum in the third decade both the mineral content and density of bone as measured by gamma transmission decrease with age in people with healthy bones. Men have a higher mineral density than women in all age groups.

3. The bone mineral density of osteoporotic hip fracture patients is lower than that of healthy controls.
Gamma transmission is the best method for measuring osteoporosis, and it can be used for population screening.

In the series of 104 hip fracture patients, 44 per cent of the women and 39 per cent of the men had one or more disease causing abnormal bone fragility. Osteomalacia was diagnosed in six of the 81 women but not in a single man.
ACKNOWLEDGEMENTS

The subject of this study was suggested to me by Docent Kauko Kettunen, M.D., Chief of the Department of Surgery, University Central Hospital of Kuopio. He has not spared his advice, encouragement, and constructive criticism in different stages of my work, and I am very happy of this opportunity to express my deep gratitude for his attention.

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To my colleagues at the University Central Hospital of Kuopio I offer my sincere thanks for their co-operation in carrying through this project. The nurses in the wards and theatre as well as in the outpatient clinic have contributed in many ways to this study. I am most grateful for their assistance.

I express my warm thanks to William F. Whimster, M.D., who revised the English text of my manuscript.

Kuopio, March, 1974

Esko Alhava
REFERENCES


FRACTURES OF THE UPPER END OF THE FEMUR
AS AN INDEX OF SENILE OSTEOPOROSIS IN FINLAND

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FROM THE UNIVERSITY CENTRAL HOSPITAL, KUOPIO, FINLAND

ABSTRACT
This epidemiological study of hip fractures in Finland reviews their frequency as
an index of osteoporosis.
Fracture of the hip is three times as common in women as in men. The incidence
increases with age. The Finnish incidence is compared with corresponding foreign
materials. Regional differences in the frequency of hip fractures in Finland merit
further study.
KEY WORDS: OSTEOPOROSIS; HIP FRACTURE

INTRODUCTION
Osteoporosis is difficult to diagnose clinically. No generally accepted methods for
the study of large populations have been introduced so far. Some idea of the
incidence of osteoporosis can be obtained from osteoporotic fractures which occur
more commonly with age, as does osteoporosis itself. Distal fractures of the radius,
upper humerus, vertebrae and upper femur can be used to indicate the incidence of osteoporosis (4). Fracture of the
upper end of the femur is the most suitable because it can be diagnosed
definitely and the victim is almost always hospitalised and, therefore, entered in the
statistics. Population studies based on the occurrence of this fracture have been conducted in the British Isles (4, 15, 27),
Sweden (1, 2, 18), Singapore (34), South Africa (25), Hong Kong (6), and Jerusalem
(17).
Several studies point to an increase in osteoporosis with age (10, 21, 24, 29, 30).
The same is true of the incidence of fractures of the upper femur (2, 27). The
mechanism of the injury is generally such that the origin of a fracture presupposes
weakness of the bones at the implicated site. These fracture patients have been
shown both by radiological and histological methods to have osteoporosis more
frequently than controls (26). In a quantitative study of femoral bone strength
in senile osteoporosis it has been demonstrated that although there was no diminu-
tion in strength per unit volume of cortical bone, the total strength of an
osteoporotic femur under static loading was 40 % less than that of normal
bone (32). Differences in the incidence of osteoporotic fractures have been estab-
lished between different populations (6). No corresponding epidemiological study
has been performed in Finland.
We set out to determine the occurrence of upper femoral fractures in Finland, to
compare it with analyses published elsewhere and to see whether there were
regional differences in the incidence.

MATERIAL AND METHODS
Our data was derived from all upper femoral fractures recorded in Finland in 1968. The
research material came from the National Board of Health statistics of patients admitted
to hospitals in that year. The hospital records of patients admitted to the Central Hospital
of Kuopio in 1968 were analysed to discover
### TABLE 1

<table>
<thead>
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<th>Age (years)</th>
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<th>Females</th>
</tr>
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<tr>
<td></td>
<td>Population</td>
<td>Number of fracture patients</td>
</tr>
<tr>
<td>Under 35</td>
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<td>53</td>
</tr>
<tr>
<td>35—39</td>
<td>151 160</td>
<td>10</td>
</tr>
<tr>
<td>40—44</td>
<td>142 769</td>
<td>15</td>
</tr>
<tr>
<td>45—49</td>
<td>118 411</td>
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<td>23</td>
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<td>55—59</td>
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<td>40 474</td>
<td>50</td>
</tr>
<tr>
<td>75—79</td>
<td>23 118</td>
<td>48</td>
</tr>
<tr>
<td>80—</td>
<td>13 963</td>
<td>78</td>
</tr>
</tbody>
</table>

### TABLE 2

**True annual incidence of upper femoral fractures in a standard population of a quarter of a million in some countries.**

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>35—39</th>
<th>40—44</th>
<th>45—49</th>
<th>50—54</th>
<th>55—59</th>
<th>60—64</th>
<th>65—69</th>
<th>70—74</th>
<th>75—79</th>
<th>80—</th>
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<td>Males</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Malmö</td>
<td>1.0</td>
<td>1.0</td>
<td>1.2</td>
<td>1.8</td>
<td>3.2</td>
<td>4.1</td>
<td>5.2</td>
<td>7.3</td>
<td>8.8</td>
<td>9.3</td>
</tr>
<tr>
<td>Jerusalem</td>
<td>2.0</td>
<td>1.9</td>
<td>1.5</td>
<td>2.3</td>
<td>2.3</td>
<td>3.0</td>
<td>8.0</td>
<td>5.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hong Kong</td>
<td>0.2</td>
<td>0.3</td>
<td>0.7</td>
<td>1.1</td>
<td>1.3</td>
<td>3.5</td>
<td>4.3</td>
<td>4.5</td>
<td>9.7</td>
<td>4.3</td>
</tr>
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<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
<td>0.4</td>
<td>0.7</td>
<td>0.8</td>
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<tr>
<td>Finland</td>
<td>1.5</td>
<td>1.1</td>
<td>1.3</td>
<td>1.5</td>
<td>1.6</td>
<td>2.1</td>
<td>4.6</td>
<td>5.5</td>
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<td></td>
<td></td>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Malmö</td>
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<td>0.7</td>
<td>1.8</td>
<td>4.1</td>
<td>6.3</td>
<td>11.2</td>
<td>19.7</td>
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</tr>
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<td>1.7</td>
<td>3.6</td>
<td>6.5</td>
<td>9.9</td>
<td>16.5</td>
<td>18.7</td>
<td>7</td>
<td></td>
</tr>
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<td>0.9</td>
<td>1.2</td>
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<td>11.9</td>
<td>15.6</td>
<td>20.5</td>
<td>39.8</td>
</tr>
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### TABLE 3

**Upper femoral fractures in two Finnish populations (P = population, N = number of fracture patients, I = true annual incidence of fractures in a standard population of a quarter of a million).**

**South-west Finland**
(The administrative district of Turku and Pori)

<table>
<thead>
<tr>
<th>Age</th>
<th>Males P</th>
<th>N</th>
<th>I</th>
<th>Females P</th>
<th>N</th>
<th>I</th>
</tr>
</thead>
<tbody>
<tr>
<td>Under 35</td>
<td>189 672</td>
<td>6</td>
<td>2.0</td>
<td>181 697</td>
<td>3</td>
<td>1.0</td>
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<tr>
<td>35—39</td>
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<td>1</td>
<td>0.4</td>
<td>21 782</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>40—44</td>
<td>21 148</td>
<td>1</td>
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<td>22 939</td>
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<td>0.7</td>
</tr>
<tr>
<td>45—49</td>
<td>17 663</td>
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</tr>
<tr>
<td>50—54</td>
<td>17 000</td>
<td>4</td>
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<td>21 488</td>
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<tr>
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<td>22 353</td>
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<tr>
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<td>7</td>
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<td>12</td>
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<td>7 459</td>
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<td>16.3</td>
</tr>
<tr>
<td>80—</td>
<td>2 144</td>
<td>19</td>
<td>13.7</td>
<td>5 279</td>
<td>82</td>
<td>37.3</td>
</tr>
<tr>
<td>Total</td>
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<td>79</td>
<td>41.5</td>
<td>353 152</td>
<td>210</td>
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<th>Age</th>
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<th>I</th>
<th>Females P</th>
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<th>I</th>
</tr>
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<td>50—54</td>
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<td>1</td>
<td>1.6</td>
<td>5 338</td>
<td>2</td>
<td>3.0</td>
</tr>
<tr>
<td>55—59</td>
<td>5 053</td>
<td>0</td>
<td>0</td>
<td>5 628</td>
<td>2</td>
<td>2.8</td>
</tr>
<tr>
<td>60—64</td>
<td>3 951</td>
<td>1</td>
<td>1.6</td>
<td>4 649</td>
<td>1</td>
<td>1.6</td>
</tr>
<tr>
<td>65—69</td>
<td>2 884</td>
<td>2</td>
<td>3.6</td>
<td>3 569</td>
<td>6</td>
<td>11.6</td>
</tr>
<tr>
<td>70—74</td>
<td>1 653</td>
<td>0</td>
<td>0</td>
<td>2 413</td>
<td>9</td>
<td>21.9</td>
</tr>
<tr>
<td>75—79</td>
<td>853</td>
<td>1</td>
<td>2.8</td>
<td>1 375</td>
<td>4</td>
<td>12.6</td>
</tr>
<tr>
<td>80—</td>
<td>531</td>
<td>3</td>
<td>8.8</td>
<td>945</td>
<td>17</td>
<td>64.0</td>
</tr>
<tr>
<td>Total</td>
<td>97 338</td>
<td>12</td>
<td>23.4</td>
<td>96 901</td>
<td>42</td>
<td>119.2</td>
</tr>
</tbody>
</table>
E. M. Ahava and J. Puittinen

Fig. 1. True annual incidence of hip fractures in a standard population of a quarter of a million in some countries.

how many of the fractures reported to the National Board of Health were caused by weakness of the bones.

RESULTS

There were 1,442 fractures of the upper end of the femur in 1968. 1,025 of the patients were females and 417 males. When all patients under 35 years were excluded, the corresponding totals were 1,372, 1,008 and 364.

Table 1 shows the population structure in Finland in 1968 and the number of upper femoral fractures for the two sexes by age groups. The true annual incidence of upper femoral fractures in Finland compared with foreign series in a standard population of a quarter of a million is presented in Table 2. Table 3: gives the population structure, the number and the incidence of fractures for the two sexes by age groups in southwest Finland and north Karelia. The five-year age groups of the persons over

Fig. 2. Patients with upper femoral fractures admitted to Central Hospital of Kuopio in 1968.

50 show a statistically significant difference (p < 0.01) for men but not for women in these two Finnish populations (t-test, paired comparison). Fig. 1 shows the true incidence of hip fracture in women and men in different populations. Fig. 2 shows the number of hip fracture patients
admitted to the Central Hospital of Kuopio in 1968. Fractures caused by severe trauma (defined as that resulting from violence more severe than a fall from the standing position, such as a fall from standing upon a chair or a table, a fall on a stairway and all traffic accidents) are more common in younger age groups and in men.

Upper femoral fractures become more frequent with advancing age. The increase in incidence is considerably greater for women than men. Fracture is three times as common in Finnish women as in men. The fracture frequency in women is greatest in Malmö (Sweden) and Jerusalem and starts to rise earlier according to the reports from these two cities. The frequency rapidly increases in Finland after the 45th year of age and is distinctly higher than in Hong Kong. It is very small in Johannesburg which differs completely from that for other localities. The male fracture frequency grows considerably more slowly. The Hong Kong, Jerusalem, Malmö and Finnish figures are much the same in this respect, but the fracture frequency for Johannesburg is again very low.

Within Finland, the incidence of upper femoral fractures in north Karelia is distinctly higher among women, whereas in south-west Finland it is higher among men.

DISCUSSION

Use of the incidence of hip fracture as an index of osteoporosis is open to criticism. To speak of an osteoporotic fracture one should be able to prove that the force causing the fracture was smaller than is needed to fracture a normal bone. It has been shown clearly that with increasing age the force causing the injury decreases and the fracture incidence increases (1, 15). Therefore, it is commonly accepted that the increasing frequency of hip fractures with advancing age is evidence of weakened bones.

The use of hip fractures as an index of osteoporosis applies to so-called senile osteoporosis best, but advanced age also brings other diseases that predispose to bone fractures. Osteomalacia has been suspected to contribute to upper femoral fractures in old women. Osteomalacia was demonstrated in 12 % of 130 hip fracture patients published from Scotland (5). Senile osteoporosis must, however, be regarded as the most important cause of upper femoral fractures in the aged. This view is supported by studies which show a correlation between senile osteoporosis and the incidence of hip fractures (26, 29).

Osteoporosis is known from clinical and experimental studies to occur in various endocrinologic diseases and also in certain deficiency states (19, 23). The extent to which conditions of this kind contribute to the genesis of senile osteoporosis has still to be explored.

Previous epidemiological studies of hip fractures record that they are more common after middle age in women in Sweden, England and Israel and that its incidence grows very fast with age. The highest incidence reported is from Sweden. The Hong Kong and Singapore series also display a distinct rise in the incidence with age, but there the ratio between the sexes changes; it is approximately 1:1 in Hong Kong, whereas in Singapore the fracture incidence in old men is double that for women.

The search for reasons for the recorded differences between populations has definitely pointed to racial factors. The bone density is distinctly greater and the incidence of hip fractures smaller among negroes than whites in America (12, 22, 28). A comparative study of Bantu women living in rural and urban environments revealed no definite differences in the incidence of hip fractures (7). The menopause occurs comitantly in different races and is therefore of no significance in this respect. Bantu men have an abnormally high urinary oestrogen level (3), which might indicate that oestrogen has a role in the genesis of osteoporosis. The importance of physical activity in connection with senile osteoporosis has been stressed (6). This is supported by the higher incidence of hip fractures in countries with a high standard of living than in underdeveloped countries. It applies particularly to women. Hip fractures are more frequent in men than in
women in countries where women are engaged in physical work up to an advanced age.

The dietary calcium and protein is probably of no special importance for senile osteoporosis, though it has proved possible in experimental conditions to produce osteoporosis by omitting these substances from the nutrition of test animals (8, 9, 11, 13, 20, 31, 33). The unimportance of calcium and protein is shown by the high incidence of hip fractures in countries such as Sweden where the milk consumption is high and the diet rich in calcium and proteins. Sufficient vitamin D is generally ingested in countries where the incidence of osteoporosis is highest. On the other hand, it is lower in regions, such as South Africa, where the incidence of hip fractures is lower, but those countries enjoy plenty of sunshine and endogenous production of vitamin D is probably adequate (16). However, adequate average consumption of various nutrients in a given population does not necessarily guarantee adequate intake in each individual. Old people are at risk for nutritional deficiencies as well as osteoporosis in developed countries too.

The standard population used in the present study comprised an adjusted quarter of a million Finnish population and similarly adjusted populations from Malmö, Jerusalem, Hong Kong, and Johannesburg. The results are therefore strictly comparable. The figures from Dundee and Singapore are not included in Table 2 as the population structures could not be elicited in sufficient detail.

Fracture of the upper end of the femur is three times more common in women than men in Finland. Under 50 it is more common in men, but after that more frequent among women. Comparison with foreign figures shows that the incidence of hip fractures among both men and women in Finland increases with age in the same way as it does in Sweden and England. There are inter-population differences in the incidence of hip fracture and for women they correspond qualitatively to the difference in the standard of living in the countries concerned. This may perhaps be accounted for by the decrease in physical activity in the countries with high living standards as these conditions improve. Our observations support the idea that osteoporosis in Finland develops earlier than Nordin suggested (22).

Helelä (14) observed regional differences in his study of variations in the thickness of cortical bones in two populations in Finland. His patients were urban, white collar workers from south-west Finland, and farmers and forest workers from north Karelia who were blue-collar workers. In the group employed in physical work the weight-bearing bones were thicker and contained more cortical bone whereas in the group engaged in sedentary work the small bones of the extremities were thicker and contained more cortical bone. According to Helelä, these differences were due to the difference in physical activity and, possibly, to different growth and nutritional conditions. South-west Finland is regarded today as an economically prospering region, whereas north Karelia is considered to be a developing area.

There are differences between south-west Finland and north Karelia in the incidence of hip fracture among both the sexes. These differences cannot, however, be explained by physical activity and possible differences in the standard of living. These fracture patients are old, and different factors have affected their skeletal development for decades. Diseases and possible deficiency states in childhood are factors that cannot be assessed in a study of this type.

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REFERENCES


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THE MINERAL CONTENT AND MINERAL DENSITY OF BONE OF THE FOREARMS IN HEALTHY PERSONS MEASURED BY Am-241 GAMMA RAY ATTENUATION METHOD

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FROM THE UNIVERSITY CENTRAL HOSPITAL, KUOPIO, FINLAND

ABSTRACT

Graphs of the mineral content (g/cm) and density (g/cm³) of the forearm bones against age for each sex have been constructed from Am-241 gamma ray attenuation measurements in 62 healthy men and 62 healthy women. Both the mineral content and density of bone decreased with increasing age after reaching a certain maximum. The bone mineral density was greater in men than women. In addition, the ratios between the stronger and weaker forearm for bone mineral content and density are reviewed.

The results will be used for studies of diseases and other factors affecting bone mineral content in the Finnish population.

KEY WORDS: BONES; Am-241, OSTEOPOROSIS

INTRODUCTION

Many important diseases, including osteoporosis, osteomalacia and rheumatoid arthritis, are accompanied by changes in the bone mineral content. Many drugs, especially steroids, also affect it.

Bone mineral has usually been measured in vivo radiologically. Unfortunately radiological errors occur, for example from changes in electric current, the continuance of the energy spectrum of roentgen radiation and, when films are used, in their quality. So the more accurate and more reliable gamma ray attenuation method has been developed in which use is made of a low energy gamma ray source of radiation and a system that measures only one quantum energy (2, 10, 11, 12).

The purpose of the present study was to produce a normal range of values which could be used as the basis for study of bone mineral changes in various diseases. The gamma attenuation method has been little used and no normal values for a healthy Finnish population are available. We assume that the bone mineral content is affected by regional factors, which are revealed, for instance, by geographical variations in the incidence of hip fractures as was shown when these fractures were employed as an index of osteoporosis (3).

MATERIAL AND METHODS

The test subjects were selected in the course of two months from ambulant patients in the University Central Hospital, Kuopio. The patients included both urban and rural dwellers and blue and white collar employees. The selection was made by interview and clinical examination. We chose 62 men and 62 women. The age distribution is presented in Figs. 1 and 2. The criteria for exclusion from the study were (14): persons who had taken hormones and had or had had an endocrinological disease, rheumatoid arthritis, malignant tumour, sarcoidosis, chronic nephropathy or renal calculi, malabsorption, osteoporosis, osteomalacia, hemiparesis or other paresis, asthma, or epilepsy, or had undergone intestinal surgery apart from appendectomy. Pregnant and lactating women and long-term users of psychopharmaceutical drugs and diuretics were also ruled out. No clinical laboratory investigations were performed for the selection procedure. Both forearms and hands were x-rayed.
Fig. 1. The mineral content in normal human bones. The means (± 1 SD) of the bone mineral content in different decades of age. Second degree regression line of the distributions. Stronger forearms denoted (x), weaker (o).

The bone mineral measurements were made by a modification (13) of the gamma radiation attenuation method (2). The source of the radiation was a 45 mCi Am-241 radionuclide, with a gamma energy of 60 keV. The forearm to be measured was fixed in a waterbath between the source and detector. At each measuring site of the bone the result was recorded as the mean of two source-detector scans across the bone. In the region of the compact bone the mineral content was calculated from the equation

\[
M_B = \frac{\Delta x \rho_m}{\mu_m \rho_m - \mu_x \rho_x} \sum_{i=1}^{n} \ln \frac{I_0}{I_i}
\]

\[\Delta x = 0.1 \text{ cm}, \mu_m = 0.395 \text{ cm}^2/\text{g}, \mu_x = 0.205 \text{ cm}^2/\text{g}, \rho_m = 2.70 \text{ g/cm}^3, \rho_x = 1.0 \text{ g/cm}^3\]

On the assumption that the shape of the cross-section of the compact bones in the
forearms are circular a mineral density index was calculated from \( \rho = M_B/A \). \( A = \pi(d_2^3 - d_1^3)/4 \), where \( d_2 \) and \( d_1 \) are the outer and inner diameters of the bones measured from x-ray pictures. Measurements of cortical bone were made at the point between the middle and distal thirds of the radius and ulna.

The measurements in the region of cancellous bone were made about 1.5 cm from the distal end of the radius. The mineral content was calculated from equation

\[
M = KM_B
\]

where \( K = 1 + a \exp\left(-b \sum_{i=1}^{n} \ln \frac{I_0}{I_i}/A\right) \),

\( a = 5.42 \) and \( b = 4.95 \) cm²

The mineral density of the distal radius was calculated from \( \rho = KM_B/A \), where \( A \) is the cross-sectional area at the measuring site.

The method used and the constants required in both methods are presented in detail elsewhere (6).

RESULTS

The measurements are presented in Fig. 1 and 2. Assuming that the distribution conforms to the shape of a parabola, a second degree regression line was plotted in the graphs for both hands. The 10-
TABLE 1

Second degree regression line \(y = a_0x^2 + a_1x + a_0\) of the measured mineral content and mineral density distributions. \(n = \) number of forearms measured, \(M_1 = \) mineral content in the metaphysis of the radius, \(M_2 = \) on the boundary of the middle and distal third of the radius and \(M_3 = \) at the corresponding site in the ulna. \(q_1, q_2, q_3\) denote mineral density at the corresponding sites.

<table>
<thead>
<tr>
<th>(n)</th>
<th>Sex</th>
<th>Mineral</th>
<th>(a_0)</th>
<th>(a_1)</th>
<th>(a_0)</th>
<th>max (or min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>124</td>
<td>M</td>
<td>M_1</td>
<td>0.0056</td>
<td>-0.1465</td>
<td>2.2100</td>
<td>(131) years</td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>M_2</td>
<td>-0.0028</td>
<td>-0.0386</td>
<td>1.7421</td>
<td>68</td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>M_3</td>
<td>0.0004</td>
<td>-0.0501</td>
<td>1.4975</td>
<td>(615)</td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>(q_1)</td>
<td>0.0013</td>
<td>-0.0295</td>
<td>0.4131</td>
<td>(112)</td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>(q_2)</td>
<td>0.0082</td>
<td>0.0693</td>
<td>0.7620</td>
<td>42.2</td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>(q_3)</td>
<td>-0.0057</td>
<td>0.0277</td>
<td>1.2630</td>
<td>24.1</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>M_1</td>
<td>0.0061</td>
<td>0.0089</td>
<td>1.1765</td>
<td>7.3</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>M_2</td>
<td>-0.0102</td>
<td>0.0694</td>
<td>0.9073</td>
<td>34.1</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>M_3</td>
<td>-0.0079</td>
<td>0.0545</td>
<td>0.7595</td>
<td>34.3</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>(q_1)</td>
<td>0.0014</td>
<td>0.0037</td>
<td>0.2874</td>
<td>13.1</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>(q_2)</td>
<td>0.0050</td>
<td>0.0108</td>
<td>0.9393</td>
<td>10.8</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>(q_3)</td>
<td>-0.0086</td>
<td>0.0489</td>
<td>1.1637</td>
<td>28.5</td>
</tr>
</tbody>
</table>

TABLE 2

The means and standard deviations of the bone mineral content and mineral density of healthy persons at different decades of age.

<table>
<thead>
<tr>
<th>Decade</th>
<th>Sex</th>
<th>(n)</th>
<th>(M_1)</th>
<th>(q_1)</th>
<th>(M_2)</th>
<th>(M_3)</th>
<th>(q_3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20—29</td>
<td>F</td>
<td>18</td>
<td>1.11±0.15</td>
<td>0.280±0.040</td>
<td>1.00±0.15</td>
<td>0.92±0.09</td>
<td>0.83±0.16</td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>18</td>
<td>1.93±0.23</td>
<td>0.387±0.055</td>
<td>1.65±0.10</td>
<td>0.89±0.12</td>
<td>1.40±0.12</td>
</tr>
<tr>
<td>30—39</td>
<td>F</td>
<td>20</td>
<td>1.17±0.20</td>
<td>0.296±0.043</td>
<td>1.01±0.14</td>
<td>0.94±0.12</td>
<td>0.83±0.14</td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>20</td>
<td>1.70±0.32</td>
<td>0.321±0.055</td>
<td>1.58±0.24</td>
<td>0.90±0.10</td>
<td>1.32±0.21</td>
</tr>
<tr>
<td>40—49</td>
<td>F</td>
<td>20</td>
<td>1.15±0.17</td>
<td>0.271±0.037</td>
<td>1.08±0.15</td>
<td>0.89±0.13</td>
<td>0.93±0.13</td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>20</td>
<td>1.69±0.18</td>
<td>0.305±0.040</td>
<td>1.52±0.18</td>
<td>0.91±0.09</td>
<td>1.27±0.12</td>
</tr>
<tr>
<td>50—59</td>
<td>F</td>
<td>22</td>
<td>1.00±0.14</td>
<td>0.267±0.036</td>
<td>0.98±0.22</td>
<td>0.86±0.14</td>
<td>0.79±0.15</td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>20</td>
<td>1.66±0.33</td>
<td>0.298±0.040</td>
<td>1.46±0.18</td>
<td>0.89±0.13</td>
<td>1.27±0.16</td>
</tr>
<tr>
<td>60—69</td>
<td>F</td>
<td>20</td>
<td>0.97±0.17</td>
<td>0.248±0.020</td>
<td>0.92±0.14</td>
<td>0.80±0.09</td>
<td>0.78±0.15</td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>20</td>
<td>1.47±0.33</td>
<td>0.288±0.057</td>
<td>1.40±0.22</td>
<td>0.91±0.13</td>
<td>1.17±0.16</td>
</tr>
<tr>
<td>70—79</td>
<td>F</td>
<td>20</td>
<td>0.83±0.11</td>
<td>0.283±0.016</td>
<td>0.83±0.16</td>
<td>0.71±0.12</td>
<td>0.72±0.12</td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>18</td>
<td>1.34±0.19</td>
<td>0.250±0.018</td>
<td>1.24±0.23</td>
<td>0.75±0.10</td>
<td>1.13±0.19</td>
</tr>
<tr>
<td>80—89</td>
<td>F</td>
<td>4</td>
<td>0.62±0.08</td>
<td>0.228±0.011</td>
<td>0.85±0.03</td>
<td>0.81±0.06</td>
<td>0.72±0.08</td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>8</td>
<td>1.47±0.23</td>
<td>0.270±0.042</td>
<td>1.28±0.11</td>
<td>0.83±0.13</td>
<td>1.14±0.16</td>
</tr>
</tbody>
</table>

DISCUSSION

Test subjects were selected to ensure that they had no disease affecting the bone metabolism and were not taking drugs that influence the mineral balance of the bones. As the age range exceeded 80 years, we included a great many elderly persons whose bone mineral content was diminished. Senile osteoporosis is thus included in this study which represents a normal series. Patients with a history of osteoporotic fractures were excluded as being cases of osteoporosis (I).

A modification (13) of the method by
TABLE 3

Some statistical results of bone mineral content $M$ (g/cm) and bone mineral density $\rho$ (g/cm$^2$) measurements. t-test, paired comparison.

<table>
<thead>
<tr>
<th>Sex</th>
<th>Meas.</th>
<th>Comparison</th>
<th>Age</th>
<th>Pairs</th>
<th>Mean ± 1SD Former</th>
<th>Mean ± 1SD Latter</th>
<th>t</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>M</td>
<td>$M_1$</td>
<td>Stronger f. — weaker f.</td>
<td>20—87</td>
<td>62</td>
<td>$1.647 ± 0.325$</td>
<td>$1.597 ± 0.315$</td>
<td>1.953</td>
<td>p &lt; 0.05</td>
</tr>
<tr>
<td>F</td>
<td>$M_1$</td>
<td>—</td>
<td>21—81</td>
<td>62</td>
<td>$1.083 ± 0.195$</td>
<td>$1.016 ± 0.186$</td>
<td>3.813</td>
<td>p &lt; 0.001</td>
</tr>
<tr>
<td>M</td>
<td>$M_2$</td>
<td>—</td>
<td>20—87</td>
<td>62</td>
<td>$1.479 ± 0.241$</td>
<td>$1.441 ± 0.219$</td>
<td>2.041</td>
<td>p &lt; 0.05</td>
</tr>
<tr>
<td>F</td>
<td>$M_2$</td>
<td>—</td>
<td>21—81</td>
<td>62</td>
<td>$0.997 ± 0.185$</td>
<td>$0.934 ± 0.173$</td>
<td>4.255</td>
<td>p &lt; 0.001</td>
</tr>
<tr>
<td>M</td>
<td>$M_3$</td>
<td>—</td>
<td>20—87</td>
<td>62</td>
<td>$1.256 ± 0.177$</td>
<td>$1.246 ± 0.196$</td>
<td>4.613</td>
<td>p &lt; 0.001</td>
</tr>
<tr>
<td>F</td>
<td>$M_3$</td>
<td>—</td>
<td>21—81</td>
<td>62</td>
<td>$0.834 ± 0.153$</td>
<td>$0.779 ± 0.144$</td>
<td>4.562</td>
<td>p &lt; 0.001</td>
</tr>
<tr>
<td>M</td>
<td>$M_4$</td>
<td>—</td>
<td>20—87</td>
<td>62</td>
<td>$0.895 ± 0.049$</td>
<td>$0.305 ± 0.053$</td>
<td>2.072</td>
<td>p &lt; 0.05</td>
</tr>
<tr>
<td>F</td>
<td>$M_4$</td>
<td>—</td>
<td>21—81</td>
<td>62</td>
<td>$0.260 ± 0.031$</td>
<td>$0.270 ± 0.044$</td>
<td>2.519</td>
<td>p &lt; 0.02</td>
</tr>
<tr>
<td>M</td>
<td>$M_5$</td>
<td>—</td>
<td>20—87</td>
<td>62</td>
<td>$0.852 ± 0.137$</td>
<td>$0.848 ± 0.141$</td>
<td>1.128</td>
<td>p &lt; 0.05</td>
</tr>
<tr>
<td>F</td>
<td>$M_5$</td>
<td>—</td>
<td>21—81</td>
<td>62</td>
<td>$0.861 ± 0.129$</td>
<td>$0.886 ± 0.118$</td>
<td>1.756</td>
<td>not signif.</td>
</tr>
<tr>
<td>M</td>
<td>$M_6$</td>
<td>—</td>
<td>20—87</td>
<td>62</td>
<td>$1.245 ± 0.174$</td>
<td>$1.222 ± 0.198$</td>
<td>1.110</td>
<td>not signif.</td>
</tr>
<tr>
<td>F</td>
<td>$M_6$</td>
<td>—</td>
<td>21—81</td>
<td>62</td>
<td>$1.176 ± 0.261$</td>
<td>$1.150 ± 0.241$</td>
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<td>not signif.</td>
</tr>
<tr>
<td>M</td>
<td>$M_7$</td>
<td>Male f. — female f.</td>
<td>21—81</td>
<td>108</td>
<td>$0.866 ± 0.122$</td>
<td>$0.850 ± 0.133$</td>
<td>1.042</td>
<td>not signif.</td>
</tr>
<tr>
<td>F</td>
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<td>—</td>
<td>21—81</td>
<td>108</td>
<td>$1.244 ± 0.183$</td>
<td>$1.176 ± 0.249$</td>
<td>2.480</td>
<td>p &lt; 0.02</td>
</tr>
</tbody>
</table>
thicker in cross section in men than in women. The cortical bones of the right forearm have higher ash contents compared with the left (15). Comparison of the mineral densities of the male and female forearm bones shows statistically significant differences for the radial metaphysis and ulnar diaphysis, but no significant difference for the diaphysis of the radius.

The mineral content is greater in the stronger than in the weaker limb, although the difference is not significant at every measuring point. In contrast, the mineral density is significantly greater in the weaker limb or no significant difference can be seen. These results are explained by the differences in bone size.

The results of the study can be used as base values in bone mineral studies of the Finnish population until separate normal values can be determined for individual populations to take account of such factors as differences in race and standard of living (3).

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MINERAL CONTENT AND DENSITY OF THE FOREARM BONES MEASURED BY Am-241 GAMMA RAY ATTENUATION METHOD IN 80 PATIENTS WITH OSTEOPOROTIC HIP FRACTURES

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ABSTRACT

The bone mineral content and mineral density of the trabecular radius was measured in vivo in 63 women and 17 men with osteoporotic hip fractures using Am-241 gamma ray attenuation. When the results were compared with the normal range by age and sex, the mean mineral density of both female and male patients was statistically significantly smaller than normal.

It seems obvious on the basis of this study that determination of the mineral density of the peripheral bones by gamma ray attenuation is suitable for screening studies in osteoporosis.

KEY WORDS: OSTEOPOROSIS; Am-241; OSTEOMALACIA; HIP FRACTURE

INTRODUCTION

Upper femoral fractures increase in old age (4, 6, 23). This is attributed to osteoporosis (3, 9), the incidence of which also increases with age. People with upper femoral fractures have been found both radiographically and histologically to have a higher incidence of osteoporosis than controls (24). Using these fractures as an index of osteoporosis has revealed great geographical differences (8). There is thus reason to assume that regional differences also exist in the bone mineral content.

The degree of osteoporosis is generally assessed in clinical routine from radiographs, which is a very inaccurate method. Histologic procedures for the evaluation of osteoporosis (5) are difficult and they require bone biopsy. In 1963 Cameron and Sorenson reported a method (7) based on gamma ray attenuation which has proved to be more accurate and reliable than radiographic methods (18). So we set out to apply the gamma ray attenuation method to the determination of the mineral content and density of the radial metaphysis in patients with hip fracture and to find out whether their bone mineral content was smaller than that of a control series. We also tried to establish whether measurement of the mineral content of peripheral bones corresponded with the picture of general osteoporosis which would make it suitable for screening studies.

PATIENTS AND METHODS

We examined 80 patients with fracture of the hip who had been admitted to the University Central Hospital of Kuopio. The descriptions of accidents suggested that the fractures had been associated with weakness of the bones.

The age distribution of these 63 women and 17 men is presented in the figure. Twenty-two women and two men had a Colles’ fracture. Thirteen women but no men had had an old vertebral fracture. Diabetes was present in 11 female cases. Three women had histologically verified osteomalacia. One woman (aged 45) had hypophosphatasia and numerous earlier fractures. She was excluded from the statistical analysis because of her high mineral content.
124 persons with healthy bones were used as controls (2). Pelvic, spinal and carpal x-rays were taken for each patient.

The bone mineral was measured using a modification (22) of the gamma radiation attenuation method (7). The source of the radiation was a 48 mCi Am-241 radionuclide, gamma energy 60 KeV. The forearm to be measured was fixed in a waterbath between the source and detector. At the measuring site of the bone the result recorded was the mean of two scans across the bone. The measurement was made about 1.5 cm from the distal end of the radius in the region of cancellous bone. The mineral content was calculated from the equation:

$$M = K M_B,$$

where

$$M_B = \frac{\Delta x}{\mu_m \rho_m - \mu_s \rho_s} \sum_{i=1}^{n} \ln \left( \frac{I_0}{I_i} \right),$$

$$\Delta x = 0.1 \text{ cm},$$

$$\mu_m = 0.395 \text{ cm}^2/\text{g},$$

$$\mu_s = 0.205 \text{ cm}^2/\text{g},$$

$$\rho_m = 2.70 \text{ g/cm}^3,$$

$$\rho_s = 1.0 \text{ g/cm}^3,$$

$$K = 1 + a \exp\left( -b \sum_{i=1}^{n} \ln \left( \frac{I_0}{I_i} / A \right) \right).$$

$a = 5.42$ and $b = 4.95 \text{ cm}^2$

The mineral density of the distal radius was calculated from $\rho = K M_B / A$, where $A$ is the cross-sectional area of the bone at the measuring site. The method used and the constants required are presented in detail elsewhere (15).

**RESULTS**

The measurements are presented in the figure which shows the regression line and standard deviation for the controls from the 30th year of age. The female mean mineral density was statistically significantly ($p < 0.001$) smaller in the fracture patients than in the controls, and the same was true of the male mean mineral density ($p < 0.05$). On the other hand, the mineral content did not differ statistically significantly from the controls in either sex. The women with a fracture of the radius had a significantly lower ($p < 0.02$) and the women with a history of vertebral fracture a highly significantly lower ($p < 0.001$) mineral density than the controls. The bone mineral density of the diabetics was smaller than that of the controls, but the difference was not statistically significant. There was no dif-

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**Fig. 1.** The mineral content and mineral density of the distal radius in 80 fracture patients. The regression line with its 1 SD for the normal material from the age of 30 is plotted.
ference in mineral density between the cervical and trochanteric fracture groups of women.

DISCUSSION

The distribution used by Alffram (1) was applied in selecting the material so severe trauma was excluded. The patients included had suffered moderate trauma, except for two who had no history of trauma. The same measuring method was used for the patients and the controls and the measurements were made by the same observers. Only one limb was measured as several patients had had a fracture of the distal end of the radius and because measurement of a wrist previously fractured gives an entirely unreliable result. As the mineral density of the radial metaphysis is lower in the stronger than in the weaker extremity (2), values corresponding to the fracture patient's age which were obtained from the regression line of the stronger and weaker limb of the control material were used as comparative values in the statistical analysis (t-test, paired comparison). The regression line presented in the figure was calculated from the means for both limbs in the normal series.

The outer diameter of the diaphysis of long bones has been observed to grow throughout life due to the continual periosteal deposition of new bone (12, 16, 21). It is obvious that there is greater growth in the diameter of the radial metaphysis in patients with osteoporosis as the mineral content (g/cm) of our fracture patients showed no difference from that of the normal population but the mineral density (g/cm²) of both male and female fracture patients was statistically significantly smaller than in the normal series.

Our measurements agree with previous observations (24) that persons with upper femoral fractures are more osteoporotic than coeval controls.

The clinical manifestations of osteoporosis are consequences of changes in the cancellous bone in the segments that bear the weight of the bones, such as the femoral neck. The predilection for cancellous bone results from the imbalance between bone formation and resorption. As the formation and resorption of bone are events which occur primarily on the endosteal surface of existing bone, cancellous bone loses bone faster than cortical bone because of the large surface which participates in the metabolism (11).

We have assumed in our study that the mineral density of the radial metaphysis gives an idea of the mineral situation of the skeleton as a whole. Several investigations (10, 17, 19, 20) show that changes in the peripheral bones are similar to those in the axial bones. Johnston (14) used the metaphysis of the radius as the measuring point in his osteoporosis studies and noted that changes occur in it rapidly and are more readily measurable than in the area of the radial diaphysis.

Osteomalacia may be an aetiological factor in hip fractures although it is also encountered coincidentally with osteoporosis (8). The measuring method that we employed does not distinguish between these two diseases. Hip fracture patients with osteomalacia were therefore included in this study.

In his study of the epidemiology of hip fractures Alffram reported a relatively great number of diabetics in his material. Hernberg (13) observed in his autopsy material that adult diabetics were more osteoporotic than the controls. In our investigation, probably because of the small numbers, no statistically significant difference was established between diabetics and the controls, though a distinct trend was observed.

It seems apparent from our study that measurement of the mineral density of peripheral bones by the gamma ray attenuation method lends itself to screening studies of large population groups. It is possible with its help to detect the high risk patients who are likely to sustain osteoporotic fractures.

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CORRELATIONS OF HISTOLOGICAL, RADIOLOGICAL AND GAMMA TRANSMISSION METHODS IN EVALUATING OSTEOPOROSIS IN PATIENTS WITH FRACTURED HIPS.

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ABSTRACT

In a series of 104 hip fracture patients osteoporosis was assessed by measuring the mean trabecular width in iliac crest bone histologically, and, in radiographs, the cortical index of femoral diaphysis and scoring the femoral trabecular pattern. The results were compared with the mineral density of the radial metaphysis measured by gamma ray transmission method. There was a good correlation between the mean trabecular width in iliac crest bone and the mineral density of distal radius. The cortical index and femoral trabecular pattern did not, however, correlate with it. This is probably due to the poor sensitivity of radiographic methods.

Key words: Osteoporosis, Am-241, radiography, bones
INTRODUCTION

Osteoporosis can only be diagnosed from radiographs when the bone mineral content has decreased by at least 30 per cent (16). Several methods have therefore been devised for measuring bone mineral content (5,10,11,17,19,28,31). The cortical thickness of long bones proved to be the simplest and easiest measurement. But several authors have used the trabecular structure to estimate the degree of mineralisation of the skeleton (12,13,21,29). For example, Singh et al. (24) thought that the degree of osteoporosis could perhaps be assessed on the basis of the trabecular structure of the upper end of femur. Cameron and Sorenson (8) introduced a method based on gamma ray transmission for the measurement of bone mineral content, which has proved to be more accurate and reliable than radiological methods (22).

Actual bone samples taken from the iliac crest have been used as another approach to the problem (6,15,27). Histologically osteoporosis is characterised by thinning and disappearance of bone trabeculae of which the weight-bearing ones disappear last. These changes can be detected by microscopical measurement of the area of bone (18) or of the average thicknesses of bone trabeculae (7). This study was undertaken to find out how osteoporosis measured by the mean trabecular width in a cancellous specimen taken from the iliac crest, the trabecular pattern of the upper end of the femur, and the cortical index of the femoral diaphysis compared with the mineral density of the radial metaphysis measured by gamma transmission in patients.
with hip fractures.

MATERIAL AND METHODS

The fracture series consisted of patients with hip fractures treated at the University Central Hospital, Kuopio, in 1970--1972. Cases in which fragility of the bones was considered to be a contributory cause of the fracture were included in the study. The criteria for selection introduced by Alffram (1) were applied. Severe trauma was excluded.

Histological specimens were taken in the operating theatre by Beck and Nordin's method (6) with a trephine approximately 2 cm behind the anterior spine of the iliac crest. The sample, a cylinder of bone 2 cm long and 1/2 cm in diameter, was fixed in 10 per cent formaldehyde. It was decalcified in formic acid and embedded in paraffin, cut and stained with hematoxylin-eosin. The microscopical measurement of the bone trabeculae (7) was performed at the middle of the trabecula to an accuracy of 10 \( \mu \text{m} \); no measurements were made of trabeculae closer than 500 \( \mu \text{m} \) to the periosteum (Fig. 1). For each patient average of 30 trabeculae were measured in the same specimen.

The cortical index of the femur was calculated radiologically by Virtama's method (28,31) in two planes perpendicular to one another at the narrowest point of the medullary canal from
the femoral diaphysis of the healthy side. The measurement of the diameter of the femur was made to an accuracy of 1 mm (d), and the cortical thicknesses at the same point denoted with a and b were combined with this value to form the cortical index, according to the formula CI = (a + b)/d.

Femoral trabecular patterns were scored by the criteria presented by Singh et al. (24) from X-rays taken from the healthy hip, and graded into six groups, with the most advanced degree of osteoporosis in grade 1 and normals in grade 6. Mineral density was determined in the fracture patients from the area of the radial metaphysis by Am-241 gamma transmission as previously described (3).

RESULTS

Statistical analysis of the parameters employed in measuring osteoporosis (Table 1) showed a significant correlation between the mean trabecular width of the iliac crest and the mineral density of the radial metaphysis in female patients and a highly significant correlation in male patients (Fig. 2). In contrast, no correlation was established between the femoral cortical index and the mineral density in either sex. The same result was obtained in both sexes when the femoral trabecular pattern and the mineral density were compared.

Comparison of the cortical index and trabecular pattern (Fig. 3)
revealed no significant correlation for women; did correlate for men. The correlation between the mean trabecular width and the cortical index (Fig. 4) was significant for women but not for men. In neither sex did the mean trabecular width of the iliac crest correlate with the trabecular structure of the upper femoral end.

DISCUSSION

The patients came from the whole area of the central hospital district of Kuopio and included both urban and rural dwellers. They may be regarded as representative of the regional occurrence of osteoporotic hip fractures.

Reproducibility within 2--5 per cent may be achieved by using gamma transmission for the determination of bone mineral content (22). The reproducibility of the method used here for the determination of mineral density was 7 per cent when one standard deviation of the dispersion is expressed as an error.

The mean trabecular width of the iliac crest was measured to an accuracy of 10 µm. Although the narrowing and disappearance of bone trabeculae is a common finding in osteoporosis, thickening and lengthening of individual trabeculae may occur in the iliac crest in elderly people (9), and this may influence the results. The trabecular structure may also change
with the depth at which the sample is taken from the upper surface of the iliac crest.

Many sources of error can affect the cortical index. They include changes in the electric power in the X-ray unit, film quality, changes in the focal distance and the thickness of the soft tissues. In addition, the cortical index measures primarily change caused by endosteal resorption which is manifested as widening of the medullary cavity with advancing age, and disregards the formation of microscopical cavities commonly observed in cortical bone, also in osteoporosis (22).

The femoral trabecular pattern can be estimated entirely subjectively and it is affected by the varus and valgus positions of the femur as well as the source of error of X-radiation (14).

Shimmins et al. (22) found mineral content measuring methods based on gamma transmission to be more accurate and more reliable than radiographic measurements based on the cortical thicknesses of the long bones. Stevens et al. (26) observed a discrepancy between the results of iliac crest biopsy (method of Beck and Nordin) and radiographical examination (method of Barnett and Nordin) in the assessment of osteoporosis. Measurements made from radiographs and based on the cortical thicknesses of long bones have proved most accurate at points where there is least soft tissue on the bone. The best results in this respect have been obtained from the second and
third metacarpal bone, with femoral cortical index measurements a little more inaccurate than these (4). According to Singh et al. (24), the femoral trabecular pattern correlates with the histological determination of cancellous osteoporosis (method of Beck and Nordin). It was shown by Kranendonk et al. (14) that the femoral trabecular pattern is not correlated with the mineral content of the radial diaphysis measured by gamma transmission.

The consensus that mineral measurements from the peripheral bones give an idea of the mineral status of the skeletal system as a whole (20,23,25) on the cancellous bone. Hence, these other investigation methods are more logical as the patients had fractures in the cancellous bone area. On the other hand, it is also rational to measure the cortical index as the patients had upper femoral fractures and, if physical factors had a role in the rate of development of osteoporosis, similar changes would probably be observable in different parts of the weight-bearing bone, in this case the femur.

It has been established in previous studies that the ash content of the extremities of the right is greater than that of the left side (30). Hip fractures occur a little more frequently on the left than the right side (1). The mineral density of the distal radius is higher in the weaker than in the stronger hand (2). Because of their assumed small practical significance, these lateral differences were not considered in the comparison of methods in the present study.
When the present results were compared, measurement based on gamma ray transmission was selected as the starting point, both because it was more accurate than the methods based on radiography (22) and as the reproducibility of the method used here was known (2). As man is known to lose 50 per cent of his cancellous bone and only five per cent of his cortical bone during his life (20), the correlation between the mineral density of the distal radius and histological study of the iliac crest is understandable. Allowing for the relatively resistant mineral loss of cortical bone with advancing age and the methodological sources of error associated with the measuring of the cortical index, it is readily understandable that no correlation was established between the femoral cortical index and the mineral density of distal radius. The measuring results obtained by using the femoral trabecular pattern in the evaluation of osteoporosis substantiate those of Kranendonk et al. (14). The more or less good correlations between the mean trabecular width of the iliac crest, the femoral trabecular pattern and the femoral cortical index are unexplained, but the relationship between the last two parameters, for example, may be influenced by local anatomical factors.
<table>
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| 5005  | <p>0.05<sup>n</sup>n = u  
= 22  
= r  
= 0.61 | not stated  
not stated  
not stated  
not stated |
| 22    | <p>0.05<sup>n</sup>n = u  
= 22  
= r  
= 0.61 | not stated  
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not stated  
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|       | <p>0.05<sup>n</sup>n = u  
= 22  
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<table>
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= 0.31 | not stated  
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| 65    | <p>0.05<sup>n</sup>n = u  
= 65  
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= 0.31 | not stated  
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|       | <p>0.05<sup>n</sup>n = u  
= 65  
= r  
= 0.31 | not stated  
not stated  
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not stated |

*Cases of osteomata were excluded.*

"Table 2. Correlation between the mineral density of the radial metaphysis (%), the mean and femoral width of the iliac crest (cm) (D)."
Fig 1. Measurement of the trabecular width of the iliac crest.

Fig 2. Scatter diagram showing the correlation between the mean trabecular width of the iliac crest and bone mineral density of the radial metaphysis.

MALES(•): \( d = 274 + \rho + 20 \)
FEMALES(•): \( d = 209 + \rho + 39 \)
Fig 3. Scatter diagram showing the correlation between the femoral cortical index and femoral trabecular pattern.

Fig 4. Scatter diagram showing the correlation between the mean trabecular width of the iliac crest and the femoral cortical index.
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DISEASES CONTRIBUTING TO FRAGILITY OF BONE IN PATIENTS WITH HIP FRACTURES.

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ABSTRACT

In a series of 81 women and 23 men, who had had a fracture of the hip as a result of moderate trauma or none at all, 44 percent of the women and 39 percent of the men had one or more disease which increase bone fragility. All patients under 50 had a disease causing bone fragility. Osteomalacia was diagnosed in six of the women but not in a single man when three of the following diagnostic criteria were satisfied: lowered calcium and phosphorus product, elevated alkaline phosphatase, a histopathological picture of osteomalacia, typical X-ray findings and response to vitamin D therapy. Changes caused by hip fracture in the serum calcium, phosphorus and alkaline phosphatase values and in the urinary hydroxyproline levels hampered their use in the diagnosis of osteomalacia.

Key words: osteoporosis, osteomalacia, hip fracture
INTRODUCTION

Hip fractures are closely related to age and sex, and senile osteoporosis is the most important predisposing factor. But that is not the only disease that may cause fragility of bones and result in fractured hips (1,12,14,31).

In this study I have analysed 104 cases of fractured hips to see which diseases had contributed a part and to assess the value of different biochemical tests in their diagnosis and management.

MATERIAL AND METHODS

The fracture series consisted of 104 patients who had hip fractures treated at the University Central Hospital, Kuopio, in 1970—1972. Cases in which fragility of bones was thought to have contributed to the fracture were included. But to exclude severe trauma, only those who had fallen to the ground from a standing position or had an equivalent injury were selected. Thus three men with upper femoral fractures were excluded from the study: one aged 31 who had fallen from a height of 10 m, a man of 30 who was hit by a falling load, and a 62-year-old man who had fallen off his motor cycle. In addition, three female patients whose general condition was poor and whose fracture were not treated were also omitted. All patients had therefore suffered a moderate injury, except for
two cases who had no history of trauma. The ages and sexes
of these patients and the types of fracture are shown in the
figure and Table 1. Three cases with subtrochanteric frac-
tures were included in the group of trochanteric fractures.
Most of the patients were admitted to hospital as emergency
cases.

Histological specimens were taken with a trephine from all
patients approximately 2 cm behind the anterior spine of the
iliac crest at the time of operative treatment (6). The sam-
ple, a cylinder of bone 2 cm long and ½ cm in diameter, was
fixed in 10 per cent formaldehyde. It was decalcified in
formic acid and embedded in paraffin. The microscopic sec-
tions were stained with haematoxylin–eosin and examined by a
pathologist. The histopathological criteria of osteomalacia
were: increased osteoblast activity (24), increased osteoclast
activity (28), increased thickness of trabeculae (21), and
disorganisation of the lamellar structure (34).

X-rays were taken of the chest, the thoracic and lumbar spines,
the pelvis and any painful areas. Within the two weeks after
fracture, the serum calcium (normal values: 9.2–11.0 mg%) (20),
serum phosphorus (normal values: 2.5–4.5 mg%) (15),
alkaline phosphatase (normal values: 0.8–2.9 BL U) (7), 24-
hour urinary excretion of calcium (normal values: 1.3–7.3 mmol),
4-hour calcium retention test (normal values: 45–60 %) (8),
24-hour urinary excretion of hydroxyproline (normal values:
70–180 for persons aged 22–65 and 50–150 µmol/m² for per-
sons over 65) (25) were estimated in most patients.
For the diagnosis of osteomalacia three of the following were required: a lowered calcium and phosphorus product (under 27 in osteomalacia) (9), a raised alkaline phosphatase level, a histopathological picture of osteomalacia, a typical X-ray finding and a return to normal in the biochemical serum changes of osteomalacia, the disappearance of clinical symptoms and improvement in roentgenological changes after vitamin D administration.

The mineral density of the radial metaphysis was determined by Am-241 gamma transmission as previously described (3).

RESULTS

Thirty six women (44 per cent of the female patients) and nine men (39 per cent of the male patients) were found to have diseases predisposing to fracture (Table 2). The late postgastrectomy syndrome was not included in the malabsorption group. The cases of osteomalacia are presented in Tables 3 and 4. The results of laboratory investigations are given in Table 5 as means, separately for the patients with osteomalacia. The alkaline phosphatase rises after fractures, so Table 6 shows the means of the serum levels grouped according to the number of days after the trauma. Only one patient outside the osteomalacia group had a raised alkaline phosphatase which could be attributed to a cause other than fracture. This patient had had a raised alkaline phosphatase for
several years and had had a laparotomy at which chronic hepatitis was diagnosed.

The histological criteria of osteomalacia were met by five women and one man. One woman was found to have a plasmo-
cytoma which had not previously been diagnosed.

One female patient had a stress fracture of the hip. Five patients had unilateral arthrosis of the hip. Of these, one woman and one man had a fracture and arthrosis in the same hip. The other three women had the fracture and arthrosis in opposite hips.

DISCUSSION

The patients came from the whole town and country area served by the central hospital district of Kuopio. I regard them as representative of the regional occurrence of osteoporotic hip fractures. The age and sex distributions as well as the relationship between fracture types was similar to that previously found (1).

In the list of diseases contributing to bone fragility (Table 2) diabetes, rheumatoid arthritis, alcoholism, epilepsy, chronic mental disease and chronic nephropathy occurred in relatively young patients. So these diseases may have relatively great importance in the origin of bone fragility, as
previous reports have emphasised (1, 17, 36, 37). The prevalence of diabetes in this series was higher among women than in Alffram's study (1). Because of the relative small number of patients with other diseases causing bone fragility the incidence in the general population could not be estimated.

The laboratory investigations have to be seen not only in the light of a serious injury with various metabolic effects, but the patients are usually old and therefore often more ill than younger patients. The laboratory tests were made without any prior dietary regimen, except for the urinary hydroxyproline determination which was preceded by a collagen-free diet for 48-hours.

The serum calcium level often declines after a fracture (32, 38), but there are diverging opinions about this (23). Nilsson et al. (32) reported a definite drop in the serum calcium level after fractures of the femoral neck which was greater than was to be expected from the loss of plasma proteins. Several previous studies have shown an increase in the serum phosphorus after fracture (32, 38). A raised serum alkaline phosphatase has also been seen after fractures (27, 32).

Old subjects with senile osteoporosis usually have a negative calcium balance and lose calcium continuously in the urine. However, this loss cannot be measured from single measurements of 24-hour urinary excretion of calcium because
it is a longterm loss of only small quantities (33), which may be increased by immobilisation (12).

Hydroxyprolines reflect collagen metabolism best as this amino acid is present virtually only in collagen (26), which is the most important protein in the bones, and increased amounts of hydroxyproline are seen in the urine in conditions in which collagen synthesis and degradation are increased (16,27). In osteomalacia the urinary excretion of hydroxyproline is increased probably because of secondary hyperparathyroidism (11).

Calcium retention studies have been evolved for the diagnosis of osteomalacia, which is characterised by inadequate mineralisation (8). It has been found, however, that active retention of calcium by the bones occurs also in osteoporosis so the diagnosis of osteomalacia cannot rest on it alone (29).

The serum calcium values tended to be lower than normal in the present study. This may be partly due to a decrease in serum proteins. The phosphorus values were tended to fall within the normal limits. These results agree with those of Nilsson et al. (32).

The serum alkaline phosphatase was studied at different times and definitely rose after the fracture occurred. The 24-hour urinary excretion of calcium was normal on the whole, except in patients with osteomalacia. The urinary hydroxyproline was usually raised both in men and women; and this rise could
be attributed to the trauma. The results of the calcium retention study were at the upper limit of normal if patients with osteomalacia were excluded.

Latent vitamin D deficiency, which may be a special risk for old women, has been given increased attention recently (4,18). In the osteomalacia series reported by Chalmers et al. (10), 21 per cent of the women had hip fracture. Piatakowski et al. (34) presented similar findings. Chalmers et al. (9) published a series of unselected hip fractures with a 12 per cent incidence of osteomalacia. The diagnostic criteria were the presence of excess osteoid, a low calcium and phosphorus product and the presence, radiologically, of Looser's zones or characteristic deformities. Although individually, these criteria were insufficient for a firm diagnosis of osteomalacia, the diagnosis could be made on two of them. No osteomalacia was seen by Hodkinson (22) in hip fracture patients when the criteria were lowered calcium and phosphorus product, elevated alkaline phosphatase and increased osteoid. Administration of vitamin D as a diagnostic method was stressed by Morgan (30). In the present study five female patients fulfilled our criteria for osteomalacia. In addition, a young woman who took drugs for epilepsy and whose response to vitamin D therapy could not be tested was put in the osteomalacia group (13). In one case of osteomalacia the diagnosis was made before the fracture on the basis of the serum calcium, phosphorus and alkaline phosphatase determinations and X-ray findings. This patient had received vitamin D therapy before
her hip was fractured and her bone mineral density was normal (Table 4, AP).

The patients with osteomalacia had a higher serum alkaline phosphatase level than other patients. The 24-hour urinary calcium excretion followed the pattern of decreased calcium excretion generally observed in osteomalacia. The mean 24-hour urinary hydroxyproline excretion was higher in the patients with osteomalacia, which agrees with previous reports (5). As there are several fractions of the plasma alkaline phosphatase (39), it was studied after heat inactivation in each case of osteomalacia. The bone fraction was raised in every case. Of course, in osteomalacia there are various aetiological factors. But in every case of osteomalacia in this series the cause could be identified. Fractures caused changes in the values of serum calcium, phosphorus, alkaline phosphatase and urinary hydroxyproline which hampered their use in the diagnosis of osteomalacia syndrome.

Hypophosphatasia is a rare congenital osseous disease encountered in varying clinical forms (35). It may also be regarded as a form of osteomalacia. The case detected in the fracture series belonged to the hypophosphatasia tarda group with multiple previous fractures, a typical appearance and low serum alkaline phosphatase (range 0-0.7 BL U). Bone biopsy revealed an osteomalacia pattern characteristic of this disease. But the mineral density of the radial metaphysis was exceptionally high, which is in disagreement with the literature. It has
been suggested that there is osteoporosis in this disease, especially in the metaphyseal areas.

Hip fractures are rare in patients with osteoarthritis of the hip (19). The bone mineral content measured radiologically from the metacarpus has been found to be greater in patients with osteoarthritis than in normal population (19). The present series included five patients with concomitant arthrosis of the hip. But the measured density of the radial metaphysis of four of them was the same or lower than in coeval controls with healthy bones. As the cases were selected on different criteria this need not necessarily conflict with previous results.

Stress fractures of the hip in an old subject must be regarded as a symptom of osteomalacia if no other cause is shown (10). A stress fracture was seen in one patient in the present series, a relatively young woman, compared with the other patients and her laboratory findings and bone biopsy were normal. She had a history of exceptional strain on her hips.
Table 1. Fractures grouped according to sex and type. Mean ages.

<table>
<thead>
<tr>
<th></th>
<th>Total number</th>
<th>Mean age</th>
<th>Cervical</th>
<th>FRACTURE TYPES</th>
<th>Mean age</th>
<th>Trochanteric</th>
<th>Mean age</th>
</tr>
</thead>
<tbody>
<tr>
<td>FEMALES</td>
<td>81</td>
<td>72.4+12.7</td>
<td>54</td>
<td>70.8+15.6</td>
<td>27</td>
<td>73.1+13.1</td>
<td></td>
</tr>
<tr>
<td>MALES</td>
<td>23</td>
<td>71.0+14.2</td>
<td>14</td>
<td>66.9+16.6</td>
<td>9</td>
<td>77.3+5.8</td>
<td></td>
</tr>
<tr>
<td>BOTH SEXES</td>
<td>104</td>
<td>68</td>
<td>36</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 4. Mineral density of the radial metaphysis of patients with osteomalacia. Normal values are taken from the first degree regression line from the age 30 onwards according to the age of the patient.

<table>
<thead>
<tr>
<th>Patients</th>
<th>Coeval healthy persons</th>
</tr>
</thead>
<tbody>
<tr>
<td>EH</td>
<td>0.226 g/cm³</td>
</tr>
<tr>
<td>AN</td>
<td>0.234 &quot;</td>
</tr>
<tr>
<td>LT</td>
<td>0.223 &quot;</td>
</tr>
<tr>
<td>AF</td>
<td>0.250 &quot;</td>
</tr>
<tr>
<td>SP</td>
<td>0.223 &quot;</td>
</tr>
<tr>
<td>AS</td>
<td>0.226 &quot;</td>
</tr>
</tbody>
</table>

Table 5. Means of some laboratory findings in patients with and without osteomalacia.

<table>
<thead>
<tr>
<th></th>
<th>Osteomalacia Females</th>
<th>Other fracture patients Males</th>
<th>Females</th>
</tr>
</thead>
<tbody>
<tr>
<td>S-Ca mg %</td>
<td>8.5±1.0</td>
<td>8.9±0.6</td>
<td>9.4±0.7</td>
</tr>
<tr>
<td>S-Pi mg %</td>
<td>3.6±0.6</td>
<td>3.4±0.5</td>
<td>3.5±0.6</td>
</tr>
<tr>
<td>Ca x Pi</td>
<td>30.0±5.8</td>
<td>30.5±5.0</td>
<td>32.2±6.3</td>
</tr>
<tr>
<td>S-Afog BL U</td>
<td>8.9±7.5</td>
<td>2.3±1.0</td>
<td>2.7±1.2</td>
</tr>
<tr>
<td>dU-Ca mmol</td>
<td>1.3±0.8</td>
<td>3.2±1.9</td>
<td>3.4±2.9</td>
</tr>
<tr>
<td>Ca ret %</td>
<td>66±14</td>
<td>59±16</td>
<td>57±14</td>
</tr>
<tr>
<td>dU-HOEnmol/m²/24 h</td>
<td>24±113</td>
<td>190±88</td>
<td>216±93</td>
</tr>
</tbody>
</table>
Table 6. Serum alkaline phosphatase of fracture patients without osteomalacia grouped according to the interval between the moment of accident and the taking of the blood sample.

<table>
<thead>
<tr>
<th>Interval (days)</th>
<th>Number of patients</th>
<th>S-Afos (BL U)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1--5</td>
<td>19</td>
<td>2.0±0.7</td>
</tr>
<tr>
<td>6--10</td>
<td>32</td>
<td>2.7±1.0</td>
</tr>
<tr>
<td>11--15</td>
<td>24</td>
<td>2.7±1.1</td>
</tr>
<tr>
<td>16--20</td>
<td>4</td>
<td>3.7±0.9</td>
</tr>
<tr>
<td>21--25</td>
<td>5</td>
<td>4.1±2.1</td>
</tr>
<tr>
<td>26--</td>
<td>6</td>
<td>2.6±0.6</td>
</tr>
</tbody>
</table>

Fig. Age and sex distributions of hip fracture patients.
REFERENCES


Table 2. Diseases contributing to fracture of the upper femur.

<table>
<thead>
<tr>
<th>Disease</th>
<th>Number of patients</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Females</td>
</tr>
<tr>
<td>Diabetes</td>
<td>13</td>
</tr>
<tr>
<td>Rheumatoid arthritis</td>
<td>5</td>
</tr>
<tr>
<td>Ankylosing spondylitis</td>
<td>0</td>
</tr>
<tr>
<td>Alcoholism</td>
<td>0</td>
</tr>
<tr>
<td>Previous thyrotoxicosis</td>
<td>4</td>
</tr>
<tr>
<td>Previous gastric surgery</td>
<td>2</td>
</tr>
<tr>
<td>Malabsorption</td>
<td>3</td>
</tr>
<tr>
<td>Epilepsy</td>
<td>2</td>
</tr>
<tr>
<td>Hypophosphatasia</td>
<td>1</td>
</tr>
<tr>
<td>Chronic mental disease</td>
<td>2</td>
</tr>
<tr>
<td>Hemiplegia</td>
<td>1</td>
</tr>
<tr>
<td>Parkinsonism</td>
<td>1</td>
</tr>
<tr>
<td>Chronic nephropathy with uremia</td>
<td>4</td>
</tr>
<tr>
<td>Myeloma</td>
<td>1</td>
</tr>
<tr>
<td>Patient/age</td>
<td>Symptomatology</td>
</tr>
<tr>
<td>-------------</td>
<td>-----------------------------------------</td>
</tr>
<tr>
<td>RH/40</td>
<td>Bone pains</td>
</tr>
<tr>
<td>AN/32</td>
<td>Fractures of both hips</td>
</tr>
<tr>
<td>LT/66</td>
<td>Multiple fractures</td>
</tr>
<tr>
<td>AP/65</td>
<td>Multiple fractures, bone pains, muscle weakness</td>
</tr>
<tr>
<td>SP/58</td>
<td>Multiple fractures, bone pains, muscle weakness</td>
</tr>
<tr>
<td>AS/57</td>
<td>Bone pains, muscle weakness, multiple fractures</td>
</tr>
</tbody>
</table>