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A COMPARISON OF THE BONE MINERAL DENSITY OF THE VERTEBRAL BODIES AND THE HIP IN ELDERLY FEMALES WITH HIP FRACTURES
Assessment Using Dual Photon Absorptiometry

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INDEXING WORDS

bone mineral density, vertebra, hip fracture, osteoporosis

SYNOPSIS

The influence of decreasing bone mineral density with age and the occurrence of hip fractures in elderly females was investigated. Normal hips were studied in 287 healthy women whose ages ranged from 20 to 90 years old. The normal hip in 61 patients who had all suffered a femoral neck or intertrochanteric hip fracture, and were over 60 years old, were also studied and compared.

The bone mineral density (BMD) of the lumbar vertebrae and the hip was measured with dual beam photon absorptiometry, for all patients. There was no correlation between the bone mineral density of the lumbar vertebral bodies, and the bone mineral density of the proximal femur. The peak bone mass in e lumbar vertebrae was seen in the thirties, but the peak bone mass in the hip was seen in the twenties.

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Bone mineral density in the lumbar vertebrae and in the hip was decreased in the patients who had sustained a hip fracture when compared to the control patients. The bone mineral density in the proximal femur was significantly reduced in patients who had sustained a hip fracture, especially in the region of Ward's triangle. These findings suggested that decreased bone mass in the hip at Ward's triangle may be correlated with the occurrence of hip fractures.

INTRODUCTION

Fractures of the hip occur frequently in the elderly population. The relationship between the increased incidence of hip fractures and changes in the bone mineral density of the hip in the elderly was investigated in this study. The bone mineral density in the lumbar vertebral bodies and the hip was measured in both healthy patients and patients who had sustained a hip fracture.

These results were then compared and analyzed.

MATERIALS AND METHODS

This study examined only women. In the first portion of this study the bone mineral density of the normal hips and lumbar vertebral bodies in 287 healthy women were studied. The ages of these patients ranged from 20 to 90 years old. These measurements were obtained to examine the changes in bone mineral density with advancing age at the lumbar vertebral bodies and hip.

In the second portion of this study, the normal hip in 61 female patients who had all suffered a femoral neck fracture, and were over 60 years old, were examined. All the fracture patients had been treated with surgical stabilization of their hip fracture, during a period of January 1986 through December 1989. These patients were classified as the "fracture group". The average age of these patients was 78.9 years and ranged from 63 years to 95 years old.

In the fracture group there were 34 right hip fractures and 27 left hip fractures. There were 36 femoral neck fractures and their average age was 77.1 years old. The femoral neck fracture patients ages ranged from 63 through 91 years old. There were 25 intertrochanteric hip fractures, and their average age was 81.5 years old. The intertrochanteric hip fracture patients ages ranged from 64 to 95 years of age.

A "control group" was established from 133 healthy women over 60 years of age. The average age of these patients was 73.1 years old. The ages ranged from 62 years old through 91 years old. The controls were mostly consisted of the patients who visited the hospital with minor other troubles without any problem on both spines and hips.

A dual beam absorpotiometer (Dichromatic Bone Densitometer 2600) made by Norland Company, U.S.A. was used to measure the bone mineral density in the lumbar vertebrae and in the proximal femur. the averaged measured values of the second, third and fourth lumbar vertebral bodies was determined and expressed as the "L mean". When lumbar vertebral fractures were seen, these vertebrae were deleted from the measurement. In the proximal femur the bone mineral density was measured at three regions (Fig. 1). These three regions were the femoral neck, the greater trochanter, and

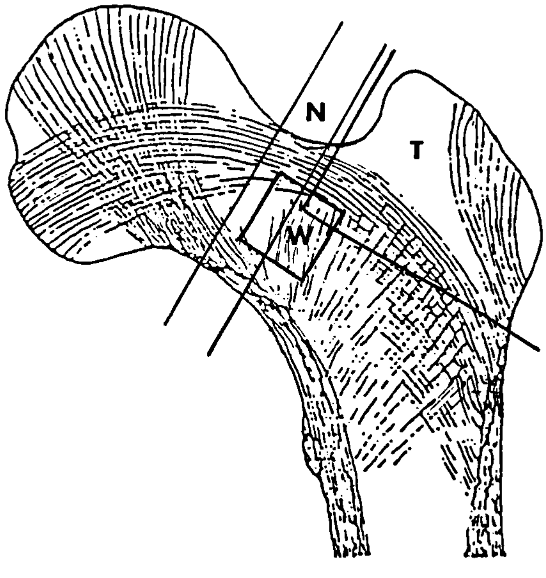

Figure 1: Three regions in the proximal femur to be measured the bone mineral density.
N: femoral neck T: greater trochanter W: Ward's triangle

Ward's triangle. The averaged measured values for these three regions of the proximal femur was expressed as the "N mean". In the patients who had sustained a fracture bone density measurements were made from the uninvolved hip.

RESULTS

1. Bone Mineral Density in Healthy Women:

The peak bone mass of the bone mineral density, "L mean", of the lumbar vertebral bodies was seen in the thirties. Thereafter, the "L mean" was observed to decrease with advancing age. Initially the "L mean" decreased slowly, but in the fifth decade of life, at the time of menopause, the decline significantly accelerated. At the conclusion of menopause the rate of the decrease of the "L mean" stabilized (Fig. 2a).

The peak bone mass of the bone mineral density "N mean" of the proximal femur was 0.832 g/cm^2. The peak bone mass was observed during the third decade of life. The BMD "N mean" decreased to 0.793 g/cm^2 in the fifth decade and 0.666 g/cm^2 in the sixth decade of life. The BMD "N mean" of the proximal femur decreased rapidly during the period of menopause, which occurred at about 45 years of age.

The measured value of the BMD at each of the three points of the proximal femur were different (Fig. 2b), and showed different patterns of change with increasing age. In the premenopausal patient the BMD in Ward's triangle, where there is abundant cancellous bone, was 0.896 g/cm^2. This measurement was higher than the BMD determined for either the femoral neck, 0.885 g/cm^2, or the greater trochanter, 0.715 g/cm^2.

At the time of menopause a significant rapid decline in the BMD at Ward's triangle was measured. In the nineth decade of life the BMD of Ward's triangle had decreased to 0.435 g/cm^2, the BMD of the femoral neck was 0.517 g/cm^2, and at the trochanter it was 0.441 g/cm^2. However, the changes at the greater trochanter and femoral neck were not as precipitous.

Cancellous bone was measured at Ward's triangle. Cortical bone was measured at the femoral neck and greater grochanter. Cancellous bone is most susceptible to menopausal related osteoporosis, whereas cortical bone diminishes with senile osteoporosis. These measurements support that concepts of menopausal and senile osteoporosis. The change of the BMD was the least decreased in the greater trochanter, which was 0.715 g/cm^2 in the third decade, and diminished to 0.441 g/cm^2 in the nineth decade.

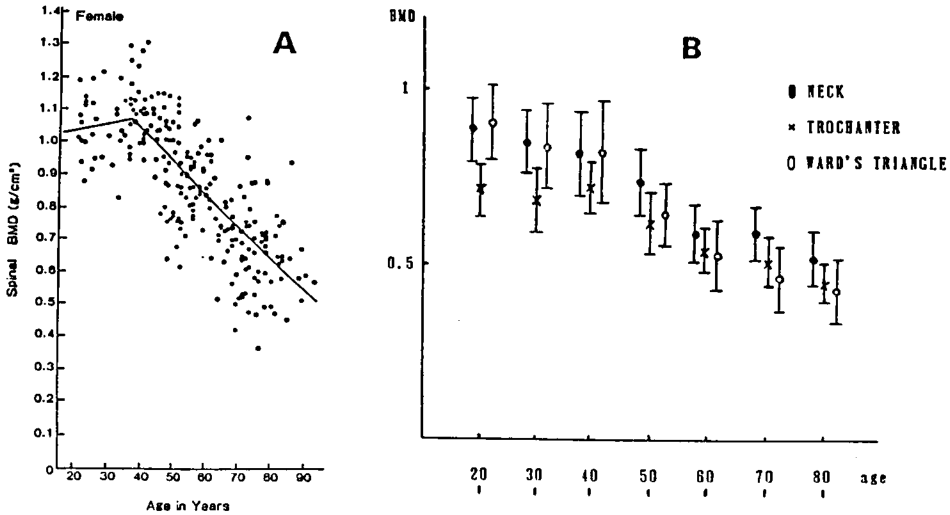

Figure 2: Bone mineral density (BMD) in healthy women.
2a: Averaged measured values of the second, third and fourth lumbar vertebral bodies, which was expressed as the " Lmean ".
2b: Measured values of BMD at each of three points of the proximal femur.

2. *Bone Mineral Density in the Fracture Group:*

Patients who were in their seventies had 50% of the fractures. Patients who were in their seventies and eighties had 80% of the hip fractures (Table 1).

Table 1 : Comparison of ages between the fracture group and the control group.

Age	Fracture group	Control group
60~69	5 cases (8.2%)	40 cases (30.0%)
70~79	30 cases (49.2%)	67 cases (50.4%)
80~89	19 cases (31.1%)	25 cases (18.8%)
90~	7 cases (11.5%)	1 case (0.8%)
total	61 cases	133 cases

A. The change of the BMD "L mean" with advancing age (Table 2)

The BMD "L mean" was 0.708 g/cm^2 in the seventh decade of life, and significantly diminished into the next decade, 0.659 g/cm^2. However, this rapid decline was not sustained and the BMD "L mean" appeared to stabilize during the nineth and tenth decades with values of 0.645 g/cm^2 and 0.647 g/cm^2 respectively.

The BMD "L mean" appeared to stabilize with advanced age. This pattern of decreasing BMD was not observed in the BMD "N mean". These measurements revealed a steady constant decrease in bone mass with advancing age. The BMD "N mean" was 0.478 g/cm^2 in the seventh decade, and it decreased to 0.405 g/cm^2 in the tenth decade. The most rapid episodic decline in the BMD occurred at Ward's triangle at the period of menopause.

Table 2 : Bone mineral density (BMD) in the fracture group.

Age	Material	Case	Lumbar Lmean	Femur Nmean	Neck	Trochanter	Ward's triangle
60~69	control	40	0.728(±0.113)	0.569(±0.073)	0.646(±0.078)	0.540(±0.063)	0.522(±0.103)
	fracture	5	0.708(±0.128)	0.478(±0.077)	0.536(±0.091)	0.447(±0.063)	0.452(±0.086)
70~79	control	67	0.714(±0.128)	0.521(±0.071)	0.596(±0.077)	0.497(±0.070)	0.471(±0.094)
	fracture	30	0.659(±0.134)	0.449(±0.088)	0.508(±0.094)	0.413(±0.083)	0.424(±0.115)
80~89	control	25	0.678(±0.111)	0.464(±0.067)	0.517(±0.078)	0.441(±0.056)	0.435(±0.093)
	fracture	19	0.645(±0.142)	0.421(±0.081)	0.472(±0.067)	0.404(±0.074)	0.386(±0.127)
90~	control	1	0.785	0.421	0.448	0.446	0.368
	fracture	7	0.647(±0.157)	0.405(±0.081)	0.468(±0.085)	0.377(±0.064)	0.369(±0.105)
Total	control	133	0.703(±0.129)	0.524(±0.080)	0.595(±0.090)	0.499(±0.074)	0.478(±0.102)
	fracture	61	0.657(±0.139)	0.438(±0.087)	0.495(±0.088)	0.409(±0.078)	0.409(±0.118)

Lmean : the averaged measured values of the second, third and fourth lumbar vertebral bodies.
Nmean : the averaged measured values for three regions of the femoral neck, the greater trochanter and Ward's triangle.

B. Comparison of bone mineral density between patients with femoral neck fractures and intertrochanteric fractures.

The patients with femoral neck fractures showed a higher value for both the BMD "L mean" and BMD "N mean", than the intertrochanteric fracture patients. However, the differences in these measurements did not have statistical significance. At each measured site of the hip region, the BMD of patients who had sustained a femoral neck fracture was slightly higher than equivalent measurements from the hips of patients with intertrochanteric fractures. However, the difference between these measurements did not have statistical significance.

Comparison of the BMD for femoral neck fractures and intertrochanteric fractures showed no statistical difference. However, the BMD of the hip and vertebral body was consistently slightly higher in the patients that had sustained a femoral neck fracture (Table 3).

Table 3 : Comparison of bone mineral density between patients with femoral neck fractures and intertrochanteric fractures.

		Lmean	Neck	Troch.	Ward's	Nmean
intertrochanteric	mean	0.627	0.479	0.392	0.381	0.419
fracture (25 cases)	SD	0.130	0.089	0.075	0.111	0.083
femoral neck	mean	0.675	0.507	0.421	0.427	0.453
fracture (36 cases)	SD	0.141	0.088	0.081	0.122	0.094

C. Comparison of bone mineral density of the left and right normal hips in patients with hip fractures.

A comparison of the BMD "N mean" and "L mean" of the left and right uninvolved hips in patients with hip fractures revealed no significant difference (Table 4).

Table 4 : Comparison of bone mineral density of the left and right normal hip in patients with hip fractures.

	Lmean	Neck	Troch.	Ward's	Nmean
right hip 34 cases	0.661	0.498	0.411	0.407	0.442
left hip 27 cases	0.649	0.491	0.406	0.410	0.436

D. Early and late comparison of bone mineral density after hip fracture.

The hip fracture patients were divided into two groups which had their BMD measurements performed either within two weeks of their fracture (early group), or after two weeks from their fracture (late group) (Table 5). There were 32 cases with early BMD measurements. There were 29 cases with measurements performed after two weeks. The BMD "L mean" was 0.04 g/cm^2, and the BMD "N mean" was 0.018 g/cm^2 higher in the late group. Specific BMD measurements at the hip for this group were: 0.021 g/cm^2 at the femoral neck, 0.011 g/cm^2 at the treater trochanter, and 0.011 g/cm^2 at Ward's triangle.

The BMD values were higher in the late group than the early group. However, there was no statistical significance between the two groups.

Table 5 : Early and late comparison of bone mineral density after hip fracture.

	Lmean	Neck	Troch.	Ward's	Nmean
early group 32 cases	0.644	0.487	0.405	0.407	0.434
late group 29 cases	0.684	0.508	0.416	0.418	0.452

early group : bone mineral density measurement was performed within two weeks from the fracture.

late group : bone mineral density measurement was performed after two weeks from the fracture.

3. Comparison Between the Fracture Group and the Control Group

A. The Comparison of bone mineral density at different ages.

1) All cases older than 60 years.

The BMD of women older than 60 years with hip fractures was compared to women over 60 in the control group (Table 6). The BMD "L mean" was 0.046 g/cm^2 ($p<0.01$) and the BMD "N mean" was 0.086 g/cm^2 ($p<0.01$) lower in the patients with hip fractures. Specific BMD measurements at the hip for the fracture group were 0.1 g/cm^2 ($p<0.01$) at the femoral neck, 0.09 g/cm^2 ($p<0.01$) at the greater trochanter, and 0.069 g/cm^2 ($p<0.01$) at Ward's triangle. The BMD in the fracture group was significantly lower than that in the control group.

Table 6 : Comparison of bone mineral density in all cases older than sixty years with hip fractures and without hip fractures.

		Lmean	Neck	Troch.	Ward's	Nmean
control group	mean	0.703	0.595	0.499	0.478	0.524
(133 cases)	SD	0.129	0.090	0.074	0.102	0.080
fracture group	mean	0.657	0.495	0.409	0.409	0.438
(61 cases)	SD	0.139	0.088	0.078	0.118	0.087

2) Examination of patients in their seventies and eighties.

A comparison of patients whose ages ranged from 70 years old to 89 years old is presented in Table 7. BMD measurements in these patients were uniformly lower than similar measurements performed on patients from the control group ($p<0.01$).

Table 7 : Comparison of bone mineral density in patients with ages ranged from seventy to eighty-nine years old.

		Lmean	Neck	Troch.	Ward's	Nmean
control group	mean	0.704	0.575	0.482	0.461	0.506
(92 cases)	SD	0.124	0.085	0.071	0.095	0.074
fracture group	mean	0.653	0.495	0.410	0.410	0.439
(49 cases)	SD	0.137	0.087	0.080	0.121	0.087

3) Comparison of BMD at each decade.

A comparison of the BMD "L mean" and "N mean" at each decade, for the fracture and the control groups, are presented in Fig. 3. At all decades the BMD in the fracture group was lower than that of the control group. There was also a larger difference between the "L mean" and the "N mean".

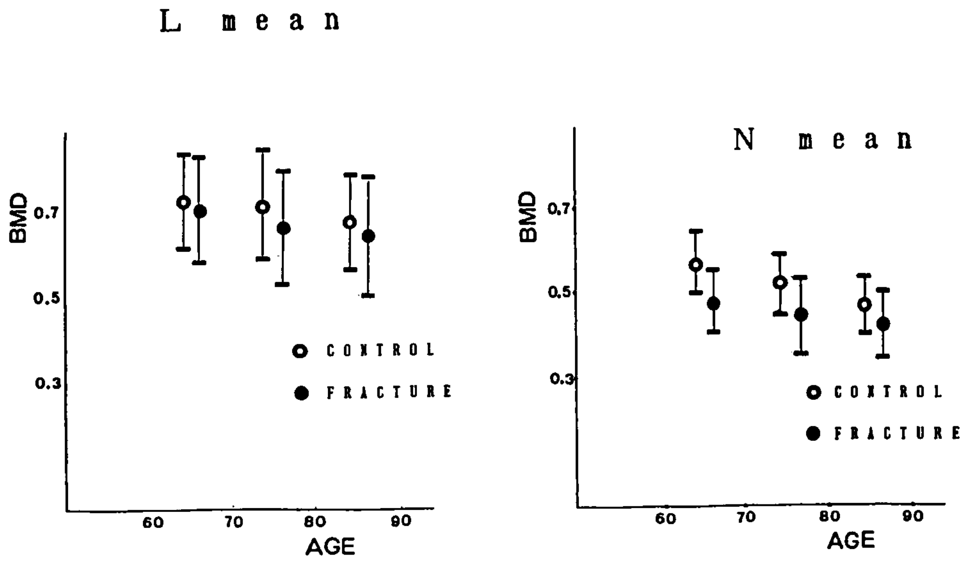

Figure 3: Comparison of BMD in Lmean and Nmean between the fracture group and the control group at each decade above sixty years old.

B. Distributional relationship between the BMD and the number of cases.

The bone mineral densities of the "L mean" and the "N mean" from patients that were within the age interval of 70 to 89 years old, were organized into increments of 0.05 g/cm^2. The number of cases from the control patients and fracture patient at each bone density was then plotted (Fig. 4).

Peak value for the BMD for the control group "L mean" was 0.65 g/cm^2. The number of control cases with BMD values above and below the peak value of 0.65 g/cm^2 was symmetrical and resembled a standard bell curve.

The peak value for the BMD for the fracture group "L mean" was 0.60 g/cm^2. The number of fracture cases with BMD values above and below the peak value of 0.60 g/cm^2 was symmetrical and resembled a standard bell curve. The distributional curve of the bone mineral densities of the fracture and control patients were similar. However, the fracture curve was significantly flatter than the control curve.

The peak bone mineral densities of the "N mean" for both the fracture and control patients were gathered in the range from 0.40 g/cm^2 through 0.50 g/cm^2. Unlike the bell shaped curve of the "L mean", the "N mean" had a more steep appearance with the majority of cases concentrated between 0.40 g/cm^2 through 0.50 g/cm^2.

The peak value of the fracture BMD of the "N mean" was 0.40 g/cm^2, the curve centered about this peak had an inclination toward the lower bone densities. The distributional curve of the "N mean" was different in shape from the distributional curve for the "L mean".

The curve of the "N mean" for the fracture patients and the control patients were not symmetrical as they had been with the "L mean". In the "L mean" the fracture curve was flatter than the control curve, with a similar distribution of cases. However, in the "N mean" the peak bone densities of the fracture curve and control curve did not coincide at similar values. The control patients and the fracture patients also showed different patterns of bone densities at the femoral neck, trochanter and Ward's triangle.

The result of the comparison between the fracture group and the control group revealed that the bone mineral density in the femoral neck was decreased when compared to the vertebral group.

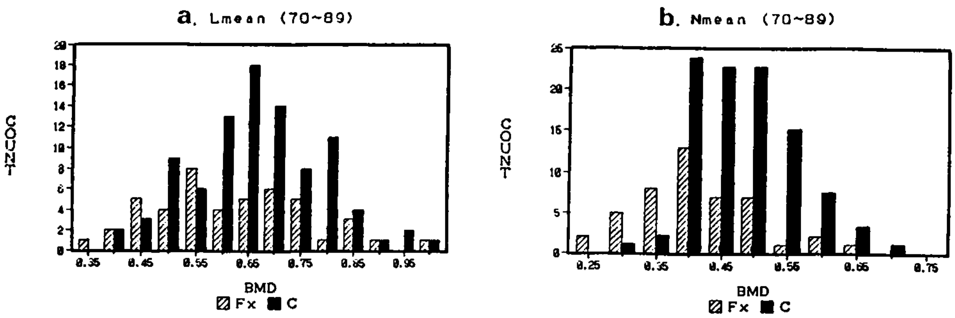

Figure 4: Distributional relationship between BMD and the number of cases ranged from seventy to eighty-nine years old.
a: Lmean b: Nmean

C. Fracture ratio at each density of bone minerals

Patients with the age range of 70 to 89 years were studied. The fracture ratio of the "L mean" and "N mean" was counted. The fracture ratio was calculated at each BMD. The calculation of the fracture ratio for each bone density was performed as follows: Fracture ratio = Percentage of the number of fracture cases /

percentage of the number of control cases. A graph of these fracture ratios is presented in Fig. 5.

The graph of the "L mean" in Fig. 5, showed that patients with a low vertebral bone mineral density had a high fracture ratio. Yet, cases which showed a high vertebral bone mineral density also had a high fracture ratio. Therefore, there was no specific correlation between bone mineral density of the vertebral body and the ratio of hip fracture.

The graph of the "N mean" in Fig. 5, showed that patients with a low bone mineral density in the hip, had a high fracture ratio. Unlike the fracture ratio of the vertebral cases, in the hip fracture group, cases which showed a high bone mineral density showed a diminished fracture ratio. In the graph of the "N mean" at the bone density of 0.40 g/cm^2 there was a very high percentage of hip fractures. This value appeared to represent a threshold density, because at higher bone densities the fracture represent rapidly decreased and resembled decreased.

The occurrence of femoral neck fractures appeared to correlate with the bone mineral density of the femoral neck. At the "N mean" value of 0.40 g/cm^2 there was a high incidence of hip fractures. The relationship between increasing bone density of the hip and decreasing hip fractures was not linear. At "N mean" BMD values higher the 0.40 g/cm^2 few hip fractures were observed.

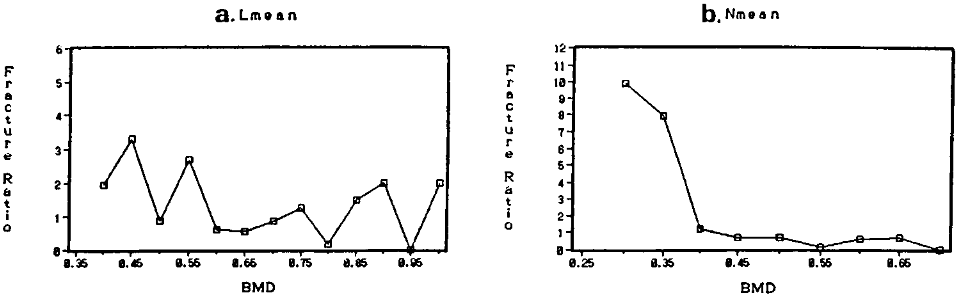

Figure 5: Fracture ratio at each density of bone minerals.
5a: Fracture ratio of Lmean in patients with the age range of seventy to eighty-nine years.
5b: Fracture ratio of Nmean in patients with the age range of seventy to eighty-nine years.

DISCUSSION

Recent technological improvements has permitted precise measurements of the change of bone mineral densities with advancing age.[11,15] Previously, isolated measurements of the forearm, fingers, or vertebrae were considered adequate to assess the extent of osteoporosis. However, it is now understood that individual bones have individual bone densities which do not reflect the general bone density of the entire skeleton.[8,9,13]

In this study, comparisons between the BMD of the vertebral bodies and the femoral neck were not always equivalent.[7] This study revealed that the maximum BMD of the lumbar vertebral body was seen at the thirties. However, the maximum bone mineral density of the femoral neck was measured at the twenties. This study also revealed that the BMD of the femoral neck began to decline at a younger age than the BMD of the vertebral bodies.

The bone mineral densities of the three sites in the hip where measurements were obtained showed subtle differences.[14] It was observed that Ward's triangle which contained abundant cancellous bone changed significantly with advancing age, and menopause. In the twenties Ward's triangle had the highest BMD. Yet, this value decreased during menopause, and in the post menopausal period showed the greatest interval decrease in BMD.

The decrease in the BMD in Ward's triangle after the twenties, but well before menopause is not understood. The authors have considered that decreased exercise in these young adults may result in some disuse osteoporosis.[4] Dietary changes in these young adults may also influence this premature decrease in BMD.

Ward's triangle contains predominantly cancellous bone.[5,6] Cancellous bone can respond more rapidly than compact cortical bone to both mechanical and metabolic changes. Early changes in the mechanical demands placed upon the hip, or metabolic stress applied to the hip can result in a premature decrease in the cancellous bone mass at Ward's triangle. The cancellous bone at Ward's triangle is sensitive to factors which can influence BMD.

In this study hip fractures not frequently occurred between 70 through 89 years of age. Measurements of the BMD of the hip and vertebral body were decreased in patients who had sustained a hip fracture when compared with the age matched female control patients.[2,3,12] There was no correlation between the interval from the time of the hip fracture until the measurement of the BMD. Post fracture disuse osteoporosis did not seem to influence the measurements of BMD from the contralateral hip.[1] The distributional curve of patient cases at specific bone densities in the hip showed a difference between hip fracture patients and controls. The hip fracture patients clustered at a lower bone density than the controls.[3] This finding suggested that hip fractures may be more likely to occur in women with decreased bone mineral density at the hip.[10]

Determination of the fracture ratio did not reveal a specific threshold value at which a vertebral fracture will occur.[16] However, determination of the fracture ratio for the hip was effective in identifying a threshold BMD value. The BMD "N mean" for the hip had a peak value of 0.40 g/cm^2 measurements, fractures were greatest below this value. The BMD "N mean" value of 0.40 g/cm^2 considered as the fracture BMD threshold.

Changes in bone mineral density alone cannot explain all the causes of hip fractures in our elderly population.[10] Additional factors which can influence the incidence of hip fractures include the increased risk of falling in the elderly, and their associated decreased ability to control their fall. However, it is difficult to obtain objective data of why and how a patient will fall.

The authors conclude that although attempts may be made to control factors which may influence a fall, this is difficult and unpredictable. Maintenance of adequate bone mineral density to withstand fractures is important for the elderly population. Determination of the bone mineral density of the hip may help identification of patients at risk of sustaining at hip fracture.

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