Computed X-ray Densitometry Measurement of mBMD & MCI in Normal Thai and Osteoporotic Patients

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Abstract

To establish the reference values of age-related change of metacarpal bone mineral density (mBMD) and metacarpal index (MCI) in screening for osteoporosis, both postero-anterior (PA) hands and lateral thoraco-lumbar radiography were done on 1,182 normal volunteers aged 17-83. From PA hands radiographs, mBMD and MCI were measured by computed X-ray densitometry (CXD) (Bonalyzer, Teijin Ltd., Tokyo). Exclusion of the surgical menopause condition and the causes of affected bone loss, the results show that mean mBMD and MCI in various age groups were significantly different (p-value < 0.005 for both) in females. Both values increased gradually from age under 20 and peaked in the 30-39 years age group, then decreased gradually until age 50 and decreased markedly after age 50. The yearly rate of bone loss from the peak density detected by mBMD and MCI was 1.3 per cent and 1.6 per cent between aged 50-59, 1.6 per cent and 2.7 per cent in subjects aged 60-69, 1.3 per cent and 3.2 per cent in those aged 70-79. However, mBMD and MCI in males did not show a downward trend with age. It indicated that a screening program for early prevention of osteoporosis may be necessary only in females before, during and after menopause. Because 92.3 per cent of 39 osteoporotic subjects had abnormal CXD measurements lower than -2 standard deviations (SD) limit of mean mBMD in young healthy women (aged 20-40 years), this value appeared to constitute a satisfactory definition of "high risk of developing osteoporosis". The incidence rate of high risk of developing osteoporosis was 3.03 per cent in a normal young population, while the risk rate occurred 4.76, 13.14, 34.28, 47.30 and 47.00 per cent in subjects aged 40-49, 50-59, 60-69, 70-79 and >80, respectively. Results confirmed the necessity of early prevention of osteoporosis in postmenopausal women. These measurements may be appropriate for mass screening to separate patients who have a greater risk for development of osteoporosis from those at lesser risk.

Key word : Age, Bone Density

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Osteoporosis is the most common metabolic disease and presents a major public health problem among the elderly[1]. The incidence of osteoporosis is expected to rise even further as the population ages[2]. Fracture is the complication that causes significant mortality, disability and is costly. Osteoporosis is now being recognized as a silent epidemic[3] and there is a great need for a simple means of identifying persons at low risk of developing osteoporosis, in order to exclude them from screening with bone mineral measurements[4]. Many measurements such as dual energy X-ray absorptiometry (DEXA),[3-9] single photon absorptiometry (SPA),[5] computed tomography,[5,7] ultrasound,[10-15] CXD[16-18] and conventional radiography[19-28] were developed and used in various sites such as the spine,[7-9] hip,[6] proximal femur,[8,29] calcaneus,[3,7,11,13-15] forearm,[8] hand[12,16,17,30] and mandible[1,31]. DEXA of the lumbar spine is the most sensitive and accurate equipment that is appropriate for definite diagnosis and follow-up,[32] but is probably inappropriate for mass screening because measurement is more expensive and it requires more space for machinery[16,24,33,34].

Bone loss occurs not only in the spine but also in the second metacarpal bone[16-18]. Measurement of bone mass for screening osteoporosis using PA hand radiographs (radiogrammetry) was first reported by Barnett and Nordin[25] and further developed involving the use of densitometry with a computer (microdensitometry)[26-28]. It has obtained low precision error, more rapid analysis and no significant difference in the Z-score when compared to spine BMD of DEXA[16].

In this study, the normal mBMD and MCI of normal Thai was established and the sensitivity of the CXD method was carried out. The cutting point for separating the high risk of developing osteoporosis from the normal population was identified. Finally, the incidence rate of high risk of developing osteoporosis in various age groups and in postmenopausal women was calculated.

MATERIAL AND METHOD

The normal volunteer group consisting of 1,023 females (18-82 yrs) and 159 males (17-83 yrs), served as subjects for studying age-related changes in the metacarpal bone. Interview of age, menopausal age, excessive use of alcohol and smoking, sedentary habits, medical data, surgical data, followed by both PA hands and lateral thoraco-lumbar radiography were done in all subjects. Exclusions included vertebral compression, deformities and diseases or conditions which affect bone such as endocrine diseases, paget's disease of bone, rheumatoid arthritis, long term immobilization, chronic kidney disease, chronic lung disease, hyperparathyroidism, medications (fluoride, calcitonin, diphosphonates, corticosteroids, antiseizure drugs), alcohol intake and cigarette smoking. Also the subjects who had a history of symptomatic fractures of the hip or vertebra were excluded.

Computed X-ray densitometry measured bone density and cortical thickness at the middle of the second metacarpal bone, using PA X-ray radiographs of the hands and an aluminium step wedge (20 steps, 1 mm/step) as a standard (Fig. 1). X-ray radiographs were scanned by light emitted diodes (LED) and charge coupled device sensors (CCD) (63.5 x 63.5 μm, 4048 U) instead of a microdensitometer. The light from the LED permitted through the X-ray film was detected by the CCD. The density signals were then converted into 256 gray values and recorded. The intensity of light from the LED could be adjusted according to the condition (the degree of whitening) of a radiograph. Using the cursor, the examiners indicated the location of the head and two points at the base of the second metacarpal bone to determine its middle basepoint. With these head and middle basepoints, a longitudinal axis could be determined and bone mass was measured on the middle of the longitudinal line. Then these data were displayed on the screen as a densitometric pattern (Fig. 2). The parameters, mBMD and MCI, were both calculated using the density data for the aluminium stepwedge. The measured mBMD expressed as the thickness of an aluminium equivalent (mm Al) corresponding X-ray absorption. MCI expressed the degree of cortical thickness. All of these analyzing processes, except identification of the line for measurement, were controlled by a computer and were executed automatically. The measuring time with this method required 7 minutes. The precision errors [coefficient of variation (CV)] were 0.2-1.2 per cent CV for mBMD and 0.4-2.0 per cent CV for MCI, respectively[16]. The results of CXD correlated closely to that of DEXA (r= 0.958)[35]. This method was performed with ordinary X-ray equipment and screen-film combination.

The mBMD and MCI of 39 osteoporotic women were studied. These subjects who had been

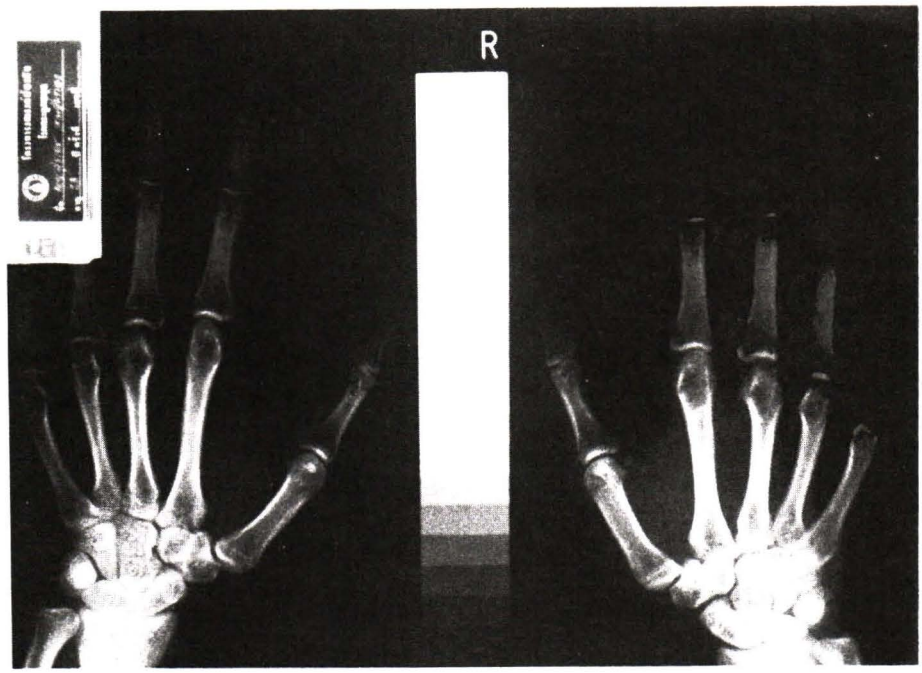
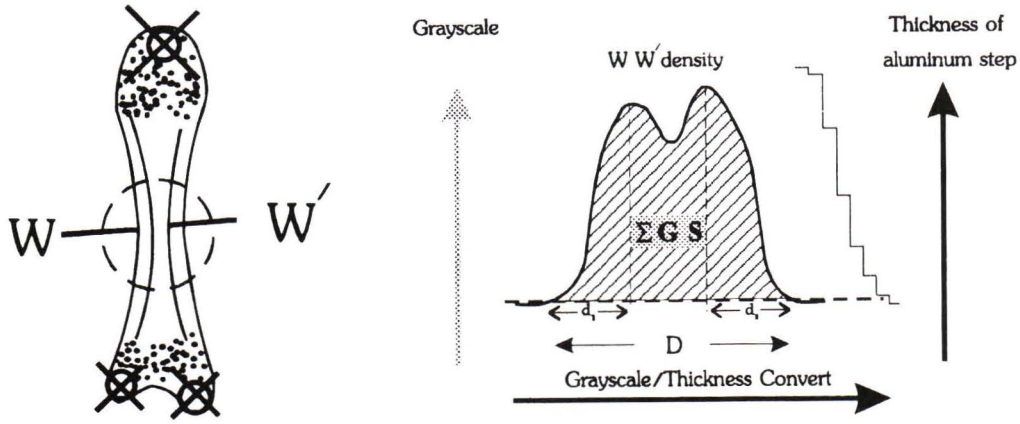


Fig. 1. Taking an X-ray image of the hands along with an aluminium step wedge.



A.
1. mBMD = ΣGS / D

B.
2. MCI = (d_1+d_2) / D

Fig. 2. A. The location of the head and two points at the base of the second metacarpal bone were indicated to determine its middle basepoint and longitudinal axis.
B. Densitometric pattern of a hand radiograph. The optical density was measured on the middle of the longitudinal line. The two parameter were measured and converted to the step numbers on the aluminium step wedge.

diagnosed by DEXA within 1 month and had two or more non traumatic vertebral compression deformities seen on radiographs of thoracic or lumbar spine, were measured and plotted for evaluation the sensitivity of CXD method.

These data were analyzed by the statistical package SPSS-PC. Standard values (mean ± SD) with the CXD method in each decade of life were calculated and plotted. Comparison of the values of both mBMD and MCI among different age groups were performed using one way analysis of variance (ANOVA), followed by the Turkey-Kramer method. Normal range (mean ± 2SD) of mBMD and MCI for age 20-40 years were calculated and used to separate the normal subjects from the subjects who had high risk for development of osteoporosis. Then the incidence rate of high risk of developing osteoporosis in a young population, age groups more than 40 and postmenopausal women were calculated. The simple regression analysis was used to establish the equation that showed the correlation of mBMD and MCI.

RESULTS

With the exclusion of surgical menopause conditions and others (as mentioned), the metacarpal bone mass in normal women is shown in Table 1. In females, mBMD and MCI in various age groups were significantly different (p-value <0.005 for both). Both values increased gradually

Table 1. Age-related change of mBMD and MCI.

age groups (yrs)	female (n=1,023) n	mBMD* (mean±SD)	MCI** (mean±SD)	male (n=159) n	mBMD (mean±SD)	MCI (mean±SD)
< 20	14	2.410±0.180	0.484±0.052	10	2.613±0.440	0.514±0.055
20 - 29	151	2.503±0.260	0.515±0.068	24	2.622±0.284	0.510±0.061
30 - 39	204	2.632±0.223	0.541±0.069	26	2.689±0.176	0.488±0.056
40 - 49	263	2.524±0.226	0.524±0.065	31	2.548±0.362	0.510±0.074
50 - 59	257	2.370±0.246	0.509±0.060	32	2.631±0.206	0.492±0.060
60 - 69	89	2.148±0.282	0.460±0.065	16	2.673±0.210	0.490±0.066
70 - 79	27	2.101±0.300	0.413±0.042	11	2.532±0.229	0.483±0.047
> 80	18	2.050±0.317	0.370±0.045	9	2.520±0.212	0.493±0.058

* mBMD below 2.145 = high risk of developing osteoporosis
** MCI below 0.383 = high risk of developing osteoporosis

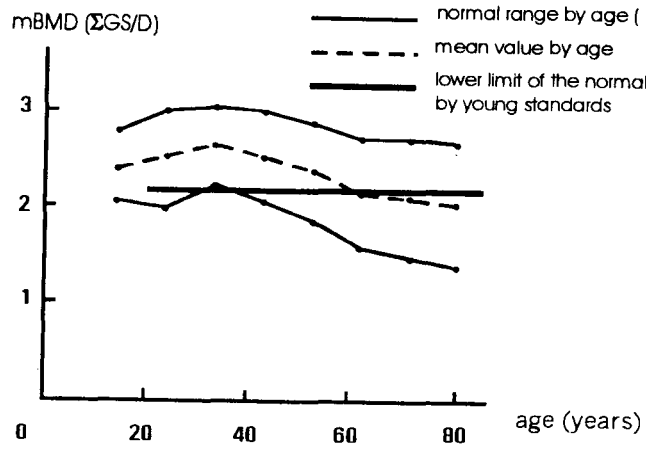


Fig. 3. Age-related change of mBMD in female.

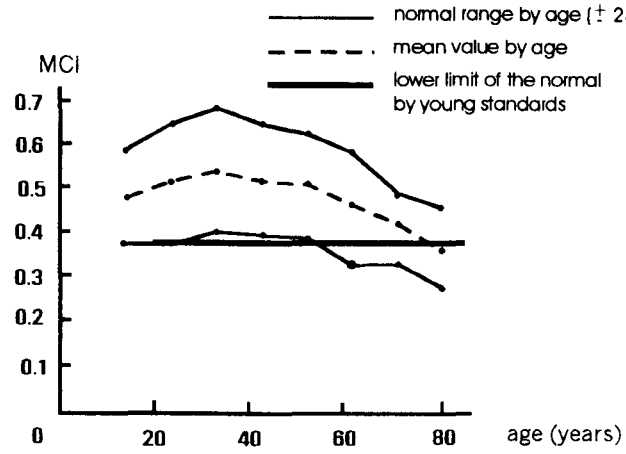


Fig. 4. Age-related change of MCI in female.

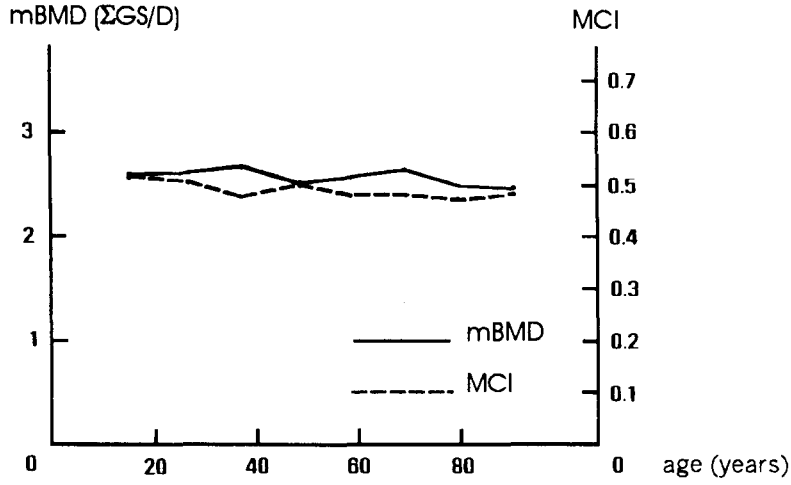


Fig. 5. Age related change of mBMD and MCI in male.

from age under 20 and peaked in the 30-39 years age group, then decreased gradually until age 50 and decreased markedly after age 50 as shown in Fig. 3 and Fig. 4. Bone diminution of mBMD and MCI yearly when compared with peak density was 1.3 per cent and 1.6 per cent between those aged 50-59, 1.6 per cent and 2.7 per cent in subjects aged 60-69, 1.3 per cent and 3.2 per cent in those aged 70-79. In males, there was no statistical difference of mBMD and MCI in various age groups (p-value = 0.316 and 0.212) as shown in Fig. 5.

The normal range for the mBMD shown in Fig. 6 was derived from the findings of mean ± 2SD (2.61±0.46) in the premenopausal women. 92.3 per cent of 39 osteoporotic women were detected by using -2SD of mean values in young healthy women as a cutting point. The incidence rate of high risk for developing osteoporosis (below -2SD of mean mBMD in young healthy women) was 3.03 per cent in the normal population, while the risk rate occurred 4.76, 13.14, 34.28, 47.30 and 47.00 per cent in subjects aged 40-49, 50-59,

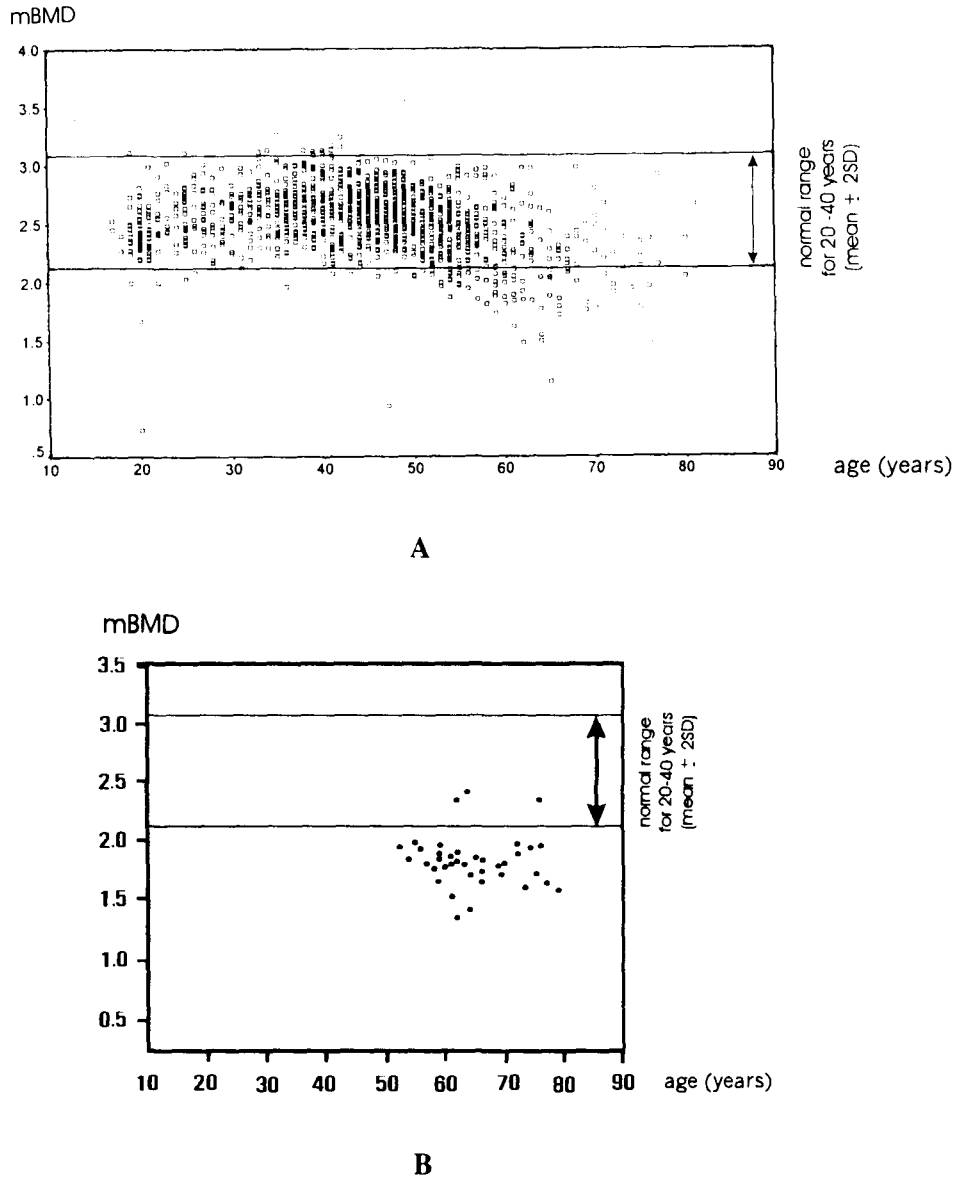


Fig. 6. Scatter plot of mBMD *versus* age in 1,182 normal subjects (A) and 39 osteoporotic patients (B), in relation to the normal by young standards.

60-69, 70-79 and >80, respectively. For an SD of 2.0 this would mean that one fifth (21.40%) of postmenopausal women were at risk (Table 2).

From simple correlation and simple regression analysis, mBMD and MCI had a positive correlation with r=0.5711 (p-value=0.001) as shown in the equation : mBMD = 1.33 + 2.30 MCI.

DISCUSSION

It was shown in women that mean mBMD and MCI in various age groups was significantly different, peaked in the 30-39 years age group, then decreased gradually until menopausal age and declined markedly after menopausal age. However, mBMD and MCI of men did not show a downward

Table 2. Number, number at risk and incidence rate of high risk of developing osteoporosis in various age groups and postmenopausal age group.

age groups (years)	n	no. at risk	incidence rate (%)
<40	429	13	3.03
40-49	294	14	4.76
50-59	289	38	13.14
60-69	105	36	34.28
70-79	38	18	47.30
>80	27	13	48.14
postmenopausal	261	56	21.40

Table 3. Comparison of age-related change of mBMD and MCI in normal Thai and Japanese women.

age groups (yrs)	Thai women (n=1,009) n	mBMD (mean±SD)	MCI (mean±SD)	Japanese women (n=1,438)(16) n	mBMD (mean±SD)	MCI (mean±SD)
20 - 29	151	2.50±0.26	0.515±0.068	239	2.70±0.19	0.549±0.056
30 - 39	204	2.63±0.22	0.541±0.069	170	2.74±0.18	0.535±0.049
40 - 49	263	2.52±0.22	0.524±0.065	411	2.70±0.17	0.549±0.046
50 - 59	257	2.37±0.24	0.509±0.060	320	2.49±0.23	0.507±0.042
60 - 69	89	2.14±0.28	0.460±0.065	159	2.22±0.24	0.437±0.039
70 - 79	27	2.10±0.30	0.413±0.042	91	1.87±0.24	0.387±0.042
> 80	18	2.05±0.31	0.370±0.045	48	1.80±0.19	0.343±0.030

trend with age. It indicated that a screening program for early prevention of osteoporosis is necessary only in females before, during and after menopause. The bone mineral content and bone mineral density of young adults is directly related to the calcium intake through milk and dietary products. A long term optimal intake of dietary calcium is an important factor for post menopausal prevention, (36) so lower bone mineral density should be detected before menopause.

Comparing this study to the study of Matsumoto et al,(16) the mean mBMD of Thai women is slightly less than the Japanese in all age groups (p-value>0.25), but MCI of Thai women is slightly higher than (p-value>0.25) the Japanese after age 50. However, the peak of mBMD and MCI at 30-39 years and the tendency of bone diminution in both countries were not different (Table 3). As these findings seem to indicate that menopause affects the change in the metacarpal measurements, the incidence rate of high risk of developing osteoporosis increases in advancing age especially after menopause (>50 years). One fifth of postmenopausal women are at risk.

When -2SD from the mean values of young healthy women (age 20-40 years) was used as the lower limit of normal measurement, abnormal CXD measurements were found in 3.03 per cent of a normal healthy Thai population. This cut off value has 92.3 per cent sensitivity for diagnosis of symptomatic osteoporosis (at least two spontaneous vertebral compressions) or in osteoporosis that has been diagnosed by DEXA. Fracture threshold that was measured by combined cortical thickness at the midshaft of the second metacarpal and at the proximal juxtametaphyseal radial cortex was 25 per cent in normal subjects and 98 per cent in osteoporotic patients(32). Below -2SD limit of young healthy women appeared to constitute a satisfactory definition for the so called "high risk of developing osteoporosis". When abnormal CXD measurements were detected , the DEXA measurements should be considered in those patients. If mBMD was normal, a repeat CXD or other screening for osteoporosis may be postponed for another 2-3 years.

In postmenopausal women, the greater the number of years since menopause, the greater the risk of osteoporosis, so early prevention of osteopo-

rosis is necessary.

The greater the decrease of bone mass, the greater the increase of fracture risk[37-40]. Measurement of BMD by CXD is simple and inexpensive. It also has a low precision error[16] with a sensitivity of 92.3 per cent and missing rate (false negative) of 7.7 per cent. Thus, CXD may be proposed for a regular health check-up mass screening program in normal subjects for early detection of bone loss (mBMD <2.145, MCI <0.383), particularly when other more expensive techniques such as DEXA are not readily available.

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การหาค่า mBMD & MCI ในคนไทยปกติ และผู้ป่วยโรคกระดูกพรุนด้วย Computed X-ray Densitometry

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ได้ทำการตรวจกรองโรคกระดูกพรุนในอาสาสมัครปกติ 1,182 ราย ช่วงอายุ 17-83 ปี เพื่อหาค่ามาตรฐานของ Metacarpal bone mineral density (mBMD) และ Metacarpal index (MCI) ในแต่ละช่วงอายุ โดยการถ่ายภาพเอกซเรย์มือทั้งสองข้างในท่า Postero-anterior (PA) และถ่ายภาพเอกซเรย์กระดูกสันหลังส่วนอกและเอวท่า Lateral จากนั้นทำการหาค่า mBMD และ MCI จากภาพเอกซเรย์มือโดยใช้วิธี Computed X-ray densitometry (CXD) (Bonalyzer, Teijin Ltd., Tokyo) ผลการวิจัยพบว่า ในผู้หญิงวัยเจริญพันธุ์และผู้หญิงที่หมดประจำเดือนตามธรรมชาติโดยไม่มีอิทธิพลของการผ่าตัดเข้ามาเกี่ยวข้อง ค่า mBMD และ MCI ในแต่ละช่วงอายุแตกต่างกัน (p-value < 0.005 ทั้งสองค่า) ค่าทั้งสองค่อย ๆ เพิ่มขึ้นจากอายุน้อยกว่า 20 จนมีค่าสูงสุดในช่วงอายุ 30-39 ปี จากนั้นจะค่อย ๆ ลดน้อยลงจนกระทั่งอายุ 50 ปี และค่าต่ำลงอย่างเห็นได้ชัด หลังจากอายุ 50 ปี การลดลงต่อปีของค่า mBMD และ MCI เมื่อเทียบกับค่าสูงสุดเป็นดังนี้ ช่วงอายุ 50-59 ปี ลดลงร้อยละ 1.3 และ 1.6 ช่วงอายุ 60-69 ปี ลดลงร้อยละ 1.6 และ 2.7 ช่วงอายุ 70-79 ปี ลดลงร้อยละ 1.3 และ 3.2 อย่างไรก็ตาม ค่า mBMD และ MCI ในผู้ชาย ไม่พบแนวโน้มการเปลี่ยนแปลงเมื่ออายุมากขึ้น ซึ่งชี้ให้เห็นว่าการตรวจกรองโรคกระดูกพรุนจำเป็นต้องทำเฉพาะในผู้หญิงเท่านั้น ทั้งก่อน ระหว่าง และหลังจากหมดประจำเดือน จากการศึกษาผู้ป่วยที่เป็นโรคกระดูกพรุน 39 ราย พบว่า ร้อยละ 92.3 ในผู้ที่เป็นโรคกระดูกพรุน มีค่า mBMD ต่ำกว่า ค่าเฉลี่ย -2 ส่วนเบี่ยงเบนมาตรฐาน (mean-2 Standard deviations) ในผู้หญิงปกติอายุ 20-40 ปี จึงใช้เกณฑ์นี้ เป็นค่าที่บอกถึงความเสี่ยงสูงต่อการเกิดโรคกระดูกพรุน พบว่า อัตราอุบัติการของความเสี่ยงสูงต่อการเกิดโรคกระดูกพรุนในคนปกติเป็น ร้อยละ 3.03 ขณะที่อัตราเสี่ยงเพิ่มขึ้นเป็นร้อยละ 4.76, 13.14, 34.28, 47.30 และ 47.00 ในช่วงอายุ 40-49, 50-59, 60-69, 70-79 และมากกว่า 80 ปี ตามลำดับ การป้องกันการเกิดโรคกระดูกพรุนในวัยหมดประจำเดือนจึงเป็นสิ่งจำเป็น การวัดความหนาแน่นของกระดูกด้วย CXD น่าจะเป็นวิธีที่เหมาะสำหรับตรวจกรองกลุ่มคนจำนวนมากเพื่อแยกผู้ที่มีความเสี่ยงสูงต่อการเกิดโรคกระดูกพรุน ออกจากผู้ที่มีความเสี่ยงต่ำ

คำสำคัญ : อายุ, ความหนาแน่นของกระดูก

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