Peripheral BMD T-Scores in the Diagnosis of Osteoporosis

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The purposes of this study were to provide the reference value of peripheral bone mineral density from young healthy adults (20-40 years) in both sexes and to examine the prevalence of osteoporosis and fracture risk in normal young adults by T-scores following the World Health Organization (WHO) definition. Non-dominant sites of 4 peripheral skeletal of 1,128 young healthy women and 225 men were examined with the following techniques: (1) dual energy X-ray absorptiometry (DXA) at supradistal and distal 1/10 of forearm (2) digital X-ray radiogrammetry (DXR) of metacarpal and distal forearm and (3) quantitative ultrasound of the os calcis (stiffness index). The results showed that young adult mean (YAM) of all peripheral sites were similar in both sexes (p>0.05 for all). Peak bone mass of all peripheral sites between Thai males and females were not different. YAM ± SD of women were used as Thai reference values and could be appropriately applied to men for individual calculation of T-scores. YAM at corresponding area of dominant and non-dominant sites of the above measurements (n=421,183 and 467 for forearm DXA, ultrasound heel and DXR, respectively) were not significantly different. It indicated that the BMD values of estimating bone mass would be correct whether the dominant or non-dominant site was measured. Applying the WHO definition of normal, osteopenia and osteoporosis to the T-scores level among 4 measurements in normal young adults for screening of peri-pheral osteoporosis, the prevalence of osteopenia and osteoporosis were 12.56-17.74% and 0.62-1.04%, respectively. There was a moderate fracture risk of 1.24-2.39% and marked risk of <0.5%

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DXA is acceptably used as the standard method for diagnosis and monitoring of osteoporosis and for assessment of fracture risk. However, axial DXA is not suitable and available for mass screening because it is usually confined to specialized centers[1]. Peripheral sites of BMD measurements may be useful to pre-select postmenopausal women in whom axial DXA is indicated to confirm/exclude osteoporosis at the spine or hip[2-8]. The non-uniform skeletal involvement in osteoporosis argues for multi-site evaluation[9,10]. Moreover, an inappropriate reference range for peak BMD may result in identification of an incorrect proportion of subjects with osteopenia and osteoporosis. Individual populations should use their own reference range T-scores to avoid misdiagnoses of osteopenia and osteoporosis [11]. BMD at different sites of healthy young adult Thai are needed, unfortunately, the values have not been reported. So the authors revealed the reference database of 4 different peripheral sites measured by DXA (Panasonic DXA-70), Ultrasound (Archillis ultrasound, Lunar) and combined radio-grammetric analysis with texture analysis (Pronosco X-posure system) or DXR in young adults (20-40 years) for T-scores in the diagnosis of osteoporosis in Thai people. YAM was calculated in both sexes because there was a different relationship between bone density and fractures in both sexes [12].

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Material and Method

The study included 1, 128 women and 225 men, aged 20-40 years (mean aged of 28.284±4.160) who were healthy and randomly selected from the screening project of osteoporosis of the department of Radiological Technology, Faculty of Medical Technology, Mahidol University from 1998 to 2001. Exclusion criteria were traumatic fractures, surgical menopause, disease or conditions known to affect bone, e.g. endocrine disease, rheumatoid arthritis, hyperparathyroidism, chronic disease, medication (current or past treatment with corticosteroids, fluoride, calcitonin, bisphosphonates). Conventional radiographs of the lateral lumbar spine were evaluated for degenera-

tive changes. Fractured vertebral bodies, if present, were excluded from the analysis. All subjects were examined at the non-dominant site with a DXA scanner of forearm, stiffness at calcaneus and DXR of hand and forearm. 114 women and 27 men could not be scanned at the non-dominant forearm because of the problem of a foreign body. 192 women and 39 men radiographs of hand including forearm for DXR measurement were also excluded because of their exposure problems. Patients were excluded if they had evidence of any secondary cause of osteoporosis and could not be scanned by any peripheral measurements. For comparison of non-dominant and dominant sites of peripheral BMD, DXA forearm, ultrasound heel and DXR measurements were also performed at both sites of 421, 183 and 467 subjects, respectively.

Forearm bone mineral density values by DXA were given in grams per centimeter squared, and the individual subjects results were expressed as T-scores. Distal forearms were scanned and BMD at 4 different regions of interest (supradistal, distal 1/10, distal 1/6 and distal 1/3) were computed. Only two regions of forearm BMD were reported because BMD at supradistal and distal 1/10 of radius had been proved a strong correlation with BMD of lumbar spine, hip, femoral neck and Ward's triangle[13]. During the same session, the subjects were examined at the calcaneus with a quantitative sonography device, the Achilles, according to the manufacturer's recommended standard procedures. The sonography derived stiffness of the calcaneus was automatically determined by the scanner software according to the following formula: stiffness = (0.67 x broadband ultrasound attenuation) + (0.28 x speed of sound) – 420[14]. Stiffness is the default parameter used by the manufacturer for demographic comparison of the patient's data, and, therefore, a T-score is given.

The recent development of computed radiogrammetric analysis of a plain radiograph of the hand and forearm was a valuable tool for quantitating bone mass[15,16]. Cortical bone loss was monitored by using the DXR method.

The diagnostic bone mass threshold for defining osteoporosis in individuals without fracture was recently clarified by the WHO[17] to be T-scores less than –2.5[18]. WHO also defined people whose BMD was normal and osteopenia if T-scores > -1 and –2.5 <T-scores <-1, respectively. T-scores of DXA were used to define moderate fracture risk by T-scores < -2 and marked risk by T-scores < -3[2].

Statistics

YAM± SD and range for reference BMD values were calculated. For comparing the means of peripheral BMDs between females and males, Student's t test was used. BMD at dominant and non-dominant of peripheral sites were compared using paired t test. Prevalence of percentage of normal, osteopenia, osteoporosis and fracture risks in healthy Thais was computed. All descriptive and inferential statistics were performed by SPSS/PC software.

Results

1,353 healthy young adults, 1,128 females and 225 males were studied aged ranging from 20-40 years. YAM ± SD of DXA BMD at supradistal and distal 1/10 of forearm, ultrasound heel and digital radiogrammetry of hand and forearm were calculated in both sexes as shown in Table 1. The Student's t test was used to compare YAM of each measurements in females and males. The results showed that YAM of all peripheral sites were similar in both sexes ($p>0.05$ for all). From paired t-test in Table 2, YAM at the corresponding area of non-dominant and dominant sites of the 4 measurements were not significantly different ($p>0.05$ for all). T-scores of individual BMD were computed using the reference YAM in Table 1. Table 3 shows the number and percentage of 3 levels of T-scores among 4 different measurements in normal young adults. There were

Table 1. YAM± SD and range of peripheral BMD in females and males

Measurement technology	sites	Females n	YAM ± SD	range	Males n	YAM ± SD	range	p
DXA	Supradistal of forearm	1,014	0.4590±0.032	0.322-0.663	198	0.5589±0.031	0.446-0.683	0.186
DXA	Distal 1/10 of forearm	1,014	0.5405±0.025	0.415-0.710	198	0.6191±0.027	0.558-0.713	0.121
Ultrasound	Calcaneus	1,128	92.4043±7.258	30-127	225	101.3600±9.114	61-139	0.124
DXR	Radius, ulna and three middle metacarpals	936	0.5538±0.030	0.482-0.642	186	0.5871±0.022	0.521-0.662	0.143

Table 2. Comparison of non-dominant and dominant sites of peripheral BMD measurements

Measurement techniques	n	$\bar{x} \pm SD$ Non-dominant	$\bar{x} \pm SD$ Dominant	p
DXA forearm (supradistal)	421	0.519±0.059	0.524±0.059	0.119
DXA forearm (distal 1/10)	421	0.471±0.074	0.483±0.067	0.132
Ultrasound calcaneus	183	91.445±14.365	91.192±14.449	0.821
DXR	467	0.560±0.032	0.568±0.032	0.415

Table 3. T-scores level among 4 different measurements in normal young Thai adults

Level of T-scores	Supradistal		Distal 1/10		Ultrasound calcaneus		DXR	
	n	%	n	%	n	%	n	%
> -1	1,025	84.57	986	81.35	1,169	86.40	960	85.56
-1 < and > -2.5	176	14.52	215	17.74	170	12.56	155	13.82
< -2.5	11	0.91	11	0.91	14	1.04	7	0.62
Total	1,014		1,014		1,128		936	

Table 4. Fracture risk level among 4 different measurements in normal young adults

Fracture risk	SDs below YAM	Supradistal		Distal 1/10		Ultrasound calcaneus		DXR	
		n	%	n	%	n	%	n	%
moderate	2	24	1.98	29	2.39	23	1.69	14	1.24
marked	3	2	0.17	2	0.17	4	0.30	0	0.00

>80% normal bone mass and <1.1% osteoporosis. <3% moderate fracture and <0.5% marked fracture risk are also shown in Table 4.

Discussion

Female and male's YAM were not significantly different as shown in Table 1. Peak bone mass of all peripheral sites in Thai males were not different from Thai females. Although axial BMD in European men were much more than women[12]. The current WHO definition of osteoporosis in postmenopausal women can be appropriately applied to men. The authors suggested that YAM ± SD of women were used as Thai reference values and could be appropriately applied to men for individual calculation of T-scores.

The standard peripheral site for screening of bone mass is the non-dominant site. Sometimes it was not practical for routine measurement because a foreign body was hard to remove. The present study showed that BMD at corresponding sites of non-dominant and dominant peripheral bone were similar. It indicated that the BMD value of estimating bone mass was correct whether the non-dominant or dominant site was measured or not.

T-scores level among 4 measurements in normal young adults in Table 3 shows 81.35-86.40% normal, 12.56-17.74% osteopenia and 0.62-1.04% osteoporosis. In comparison to the screening test for osteoporosis in 2,789 women aged 51-75 years, 34% of patients were osteoporotic, 42% were osteopenic and 24% had normal bone density results performed by spinal DXA[19]. Fracture risk level in normal young Thais were 1.24-2.39% moderate and <0.5% marked fracture risk. Although the occurrence of osteoporosis and marked fracture risk were low in normal young adults, maintenance of peak bone mass since young adult life by promoting bone formation and reducing bone resorption should be regarded for the prevention of osteoporosis fracture.

There is a need for low cost screening methods to detect low bone mass in postmenopausal women. Peripheral measurement techniques are attractive because the equipment cost is substantially lower, radiation exposure is small, the devices require less space and sometimes they are portable[20]. Computed radiogrammetry of appendicular bone densitometric method[16,21], forearm DXA[8,22,23], stiffness index of the os calcis[24,25] confirmed their predictive ability for fragility fractures.

The BMD values are expressed in terms of the number of standard deviations above or below the young normal value (commonly referred to as the T-scores). If the normative populations of the various systems are consistent, the standard deviation scores

should also be consistent. For this reason, the WHO recently established diagnostic criteria for osteoporosis base on T-scores but not BMD[26]. The patients were categorized into three diagnoses: normal, osteopenia and osteoporosis [27]. The classification of osteoporosis varies according to skeletal site [10], which is affected by multi-factors (aging, calcium intake, estrogen, life style, geographic area, etc.). The reliable prevalence of accurate diagnosis of osteoporosis and fracture risk for Thai people require Thai reference database of T-scores. In the present research, young healthy adults mean and standard deviation of bone density of 4 different peripheral measurements were established for the calculation of T-scores. They were useful for diagnosis and assessment of the fracture risk of osteoporosis in a Thai population. Because of the fracture risk increase with decreasing BMD, these important findings may lead to public health planning in promoting and preventing a health policy.

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ความหนาแน่นของกระดูกระยางค์สำหรับคำนวณ T-scores ในการวินิจฉัยโรคกระดูกพรุน

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วัตถุประสงค์ของงานวิจัยนี้คือ หาค่าอ้างอิงของความหนาแน่นของกระดูกระยางค์ จากผู้ใหญ่วัยหนุ่มสาว (20-40 ปี) ที่มีสุขภาพแข็งแรง ทั้งเพศชายและหญิง และเพื่อหาอัตราอุบัติการณ์เกิดโรคกระดูกพรุนและความเสี่ยงต่อกระดูกหักจากค่า T-scores ที่นิยามโดยองค์การอนามัยโลก ทำการวัดกระดูกระยางค์ 4 ตำแหน่งเฉพาะข้างที่ไม่ถนัดของผู้หญิง 1,128 คนและผู้ชาย 225 คน โดยใช้วิธีวัดดังนี้ (1) การดูดกลืนเอกซเรย์ 2 ค่าพลังงานที่กระดูกปลายแขนส่วนปลายสุดและส่วนปลาย 1/10 (2) รูปร่างของกระดูกฝ่ามือและปลายแขน และ (3) คลื่นเสียงความถี่สูงที่ส้นเท้า ผลการวิจัยพบว่าค่าเฉลี่ยของความหนาแน่นของกระดูกระยางค์ทุกแห่งในผู้หญิงและผู้ชาย ไม่พบความแตกต่าง (P>0.05 ทุกตำแหน่ง) นั่นคือมวลกระดูกสูงสุดของกระดูกระยางค์ในผู้หญิงและผู้ชายไม่ต่างกัน จึงสามารถใช้ค่าเฉลี่ยมวลกระดูกในผู้หญิงเป็นค่าอ้างอิงของคนไทย และสามารถประยุกต์ใช้กับการคำนวณ T-scores ในผู้ชายได้ ค่าเฉลี่ยความหนาแน่นของกระดูกระยางค์ข้างที่ไม่ถนัดและถนัดทั้ง 4 ตำแหน่ง (n = 421, 183 และ 467 สำหรับการวัดการดูดกลืนเอกซเรย์ 2 ค่าพลังงานที่ปลายแขน, คลื่นเสียงความถี่สูงที่ส้นเท้าและวัดรูปร่างของกระดูกตามลำดับ) ไม่แตกต่างกัน แสดงว่าค่าความหนาแน่นของกระดูกที่ได้จะถูกต้องไม่ว่าจะวัดข้างที่ไม่ถนัดหรือถนัด จากการใช้นิยามขององค์การอนามัยโลก พบว่าในวัยหนุ่มสาวไทย มีอุบัติการณ์เกิดกระดูกบางร้อยละ 12.56-17.74 เกิดโรคกระดูกพรุน ร้อยละ 0.62-1.04 ความเสี่ยงต่อการเกิดกระดูกหักระดับปานกลาง พบร้อยละ 1.24-2.39 และระดับสูง พบร้อยละ <0.5