Spinal Bone Mineral Density by Quantitative Computed Tomography in Thais Compared with Westerners

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The present study was to determine age- and gender-based spinal bone mineral density (BMD) by quantitative computed tomography (QCT) in Thais and to compare it with that of Westerners. Four hundred and twenty five healthy Thais, age 20 to 76 years (322 females, mean age 43.4 years;103 males, mean age 42.8 years) were recruited for BMD assessment by QCT. Spinal BMD peaks in the 20-29 year age group in both genders with a mean value of 171.9 mg/cu cm in females and 171.0 mg/cu cm in males. It subsequently decreases in older age groups. Males' BMD has a higher rate of decline than females' until age 40-49. It then stabilizes from 50-59 while females' BMD shows the highest rate decline at this period. After the mid-50's, both genders have bone loss from aging. Compared to Westerners, peak bone mass is reached in the same age group in both genders. Peak bone mass of Thai females is significantly higher than Western females, but that of Thai males is not significantly higher than Western males.

BMD of Thai males in the 50-59 and over-60 age groups is higher than that of Westerners. The findings suggest that the cut-off points for osteopenia and osteoporosis,in Thai females are at spinal BMD lower than 143.6 mg/ cu cm and 101.15 mg/ cu cm, respectively. While the values lie at 143.2 mg/ cu cm and 101.5 mg/ cu cm among Thai males for osteopenia and osteoporosis, respectively.

Keywords: *Quantitative computed tomography (QCT), Bone mineral density (BMD)*

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The currently accepted conceptual definition of osteoporosis is that it is a systemic skeletal disease characterized by low bone mass and microarchitectural deterioration of bone tissue, with a consequent increase in bone fragility and susceptibility to low-trauma or atraumatic fractures[1]. Osteoporosis is a major public health threat for more than 28 million Americans, 80% of whom are women. In the US today, 10 million individuals already have the disease and 18 million more have low bone mass, placing them at increased risk for osteoporosis. Osteoporosis is responsible for more than 1.5 million fractures annually, including 700,000 vertebral fractures, 300,000 hip fractures, 250,000 wrist fractures, and 300,000 fractures at other sites. Women can lose up to 20% of their bone mass in the 5-7 years following menopause, making them more susceptible to osteoporosis. Significant risk has been reported in people of all ethnic backgrounds. The estimated annual national direct expenditure (hospitals and nursing homes) for osteoporotic and associated fractures is $13.8 billion ($38 million each day), and the cost is rising. Osteoporosis is often called the "silent disease" because bone loss occurs without symptoms. People may not know that they have osteoporosis until their bones become so weak that a sudden strain, bump, or fall causes a fracture or a vertebral collapse[2]. Bone mineral density (BMD) measurement is the best way to make the diagnosis of osteoporosis and is a much more powerful indicator of fracture risk than cholesterol determination is a predictor of myocardial infarction[3-5]. Quantitative computed tomography (QCT) can determine in three dimensions the true volumetric density (mg/cm^3) of trabecular or cortical bone at any skeletal site. However, because of the high respon-

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siveness of spinal trabecular bone, and its importance for vertebral strength, QCT has been principally employed to determine trabecular bone density in the vertebral centrum[6,7] and QCT has been used for assessment of vertebral fracture risk[3,8], measurement of age-related bone loss[9,10], and follow-up of osteoporosis and other metabolic bone disease[4].

Age and gender greatly influence BMD, but ethnicity affects it as well. QCT is a widely accepted method for measurement of trabecular bone and for assessment of vertebral fracture risk. Motivated by these considerations, the authors performed spinal BMD by QCT in Thais to determine normative values.

Material and Method

Population and Subject

The study targeted Thai people aged 20 years or older who were healthy and joined the program voluntarily. The eligibility criteria, including inclusion and exclusion criteria, were as follows:

Inclusion criteria:

1. Healthy native Thais.
2. Age 20 or older.

Exclusion criteria:

1. History of chronic illness (more than 2 weeks in the last 12 months).
2. History of cancer.
3. Digestive tract diseases that disturb digestion and absorption.
4. Administration of anticonvulsive, diuretics, steroids, anti-platelet aggregation or contraceptive.
5. Kidney, adrenal, liver, thyroid, parathyroid, or pituitary disease.
6. Bone marrow disease or anemia.
7. Hypogonadophism or hormonal disturbance such as menopause before 40 or oophorectomy.
8. Heavy smoking or alcoholism.
9. History of low-trauma or atraumatic fracture.
10. No history of fracture or trauma to the spine, but the scout film on QCT showed an anterior wedge of a vertebral body of more than 20% of the height.

All the subjects who were eligible were then categorized by age into 10-year intervals.

Research Setting and Research Duration

The present study was conducted from January 2001 through April 2002 at the Department of Radiology, Lerdsin Hospital in Thailand.

Study Tools

A Siemens Somatom Plus scanner (Siemens, Erlangen, Germany) and a solid calibration phantom (Image Analysis, Irvine, CA) was used for BMD measurement. The bone measurement was undertaken in conjunction with history interview.

Data Collection

Using a lateral scout view to define the scan levels, a 10 mm slice thickness in the central portion of three vertebral bodies (L1-3) was obtained. If there was a spine collapse or anterior wedge of more than 20%, the subject would be excluded[11]. The rest would undergo the processes described below.

Data Analysis

The data from each subject were collected and categorized into 5 groups of 10-year age intervals: 20-29, 30-39, 40-49, 50-59, and more than 60 years, respectively. The mean of each group was obtained and compared to the one obtained from counterparts in other ethnic groups including Chinese[12], American[10], and European populations[13] for significant difference at the 95% confidence interval. Also, the change between the mean of each age group was calculated and tested for significant difference. The relationship between BMD values at different lumbar levels and age was explored in both genders. Trabecular and cortical BMD measurements were explored and their relationship with age in both genders was also identified.

Statistical Analysis

Excel for Windows was used in the statistical analysis. Descriptive statistics for continuous variables were obtained, including mean, standard deviation. Student's t-test was used to compare between the age group.Linear and Polynomial regression were applied to estimate the BMD in each age group as well as the correlation coefficient and coefficient of determination (R^2), the p-value of less than 0.05 was considered significant.

Results

Four hundred and twenty-five healthy Thais underwent BMD measurement by QCT and their demographics appear in Table 1.

According to the tool; the BMD values were corrected for body size (height and weight) in addition to age. The p values changed very little for the spinal measurements [14]. Body weight in the range of the present study did not affect the BMD value from QCT

so the authors were not concerned about subjects who had BMI over 25%. The average female BMD values of trabecular bone (L1, 2 and 3) plotted against age prefers the polynomial pattern ($r = 0.72$, $p < 0.001$) to the linear ($r = 0.69$, $p < 0.001$) (Fig. 1).From the graph, the BMD values obviously change between the ages of 35 and 55.

Formulas describing the change were calculated from the data (Table 2). The BMD values were then categorized into 3 different rates of change. That is, the lowest rate is for the 20-35 age range, while the highest rate is for the ages between 36-55 years. The last age range is from over 56 to 76 (relevant formula in Table 2). In Fig. 2, the mean BMD values and standard deviations in a ten-year interval group, present two different slopes. The steeper one is in the 40-49 age range, and the less steep one is in the over-50 age range. In females, BMD values show that peak bone mass among Chinese, American, European, and Thais occurs at the same 20-29 age group and decrease with age thereafter (Table 3). Thai females' peak bone mass is significantly higher than that of Europeans and is significantly lower than that of Chinese but is not different from that of Americans. In the 30-39 age range,

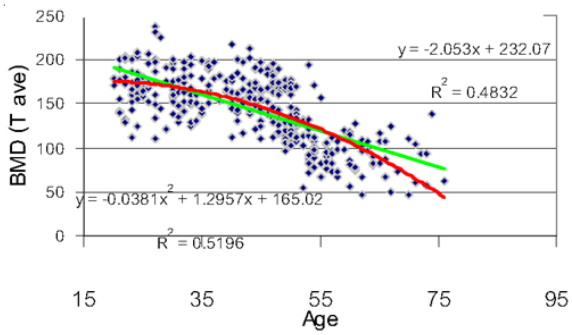

Fig. 1 Tave vs age among female subjects

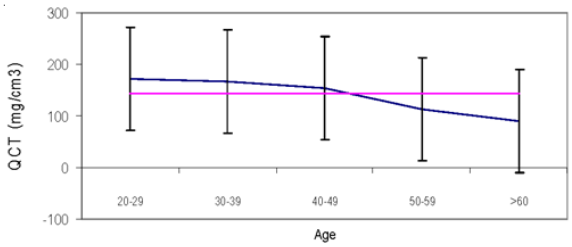

Fig. 2 BMD values (mean SD) in Thai females assessed by QCT

Table. 1

	Female	Male
Number	322	103
Age (years)	43.40±13.20 (range 20-76)	42.80±13.20 (range 20-70)
Weight (kilograms)	54.90±8.80 (37-85)	66.56±10.07 (44-95)
Height (cm)	155.80±5.40 (142-173)	167.20±6.20 (150-184)
BMI (kg/ m2)	22.65±3.61 (14.82-33.20)	23.81±3.31 (16.36-33.66)
Numbers who BMI > 25%	71 (22.0%)	32 (31.1%)

Table. 2

Gender	Age group (years)	Formula	r	p
Female (n = 322)	20-76	BMD = 232.07 – 2.053 age (Linear)	0.69	<0.001
		BMD = 165.02 – 0.0381 age2 + 1.2957 age (polynomial)	0.72	<0.001
	20-35	BMD = 236.82 – 0.0063 age (Linear)	0.05	>0.05
	36-55	BMD = 322.39 – 3.7431 age (Linear)	0.53	<0.001
	>56	BMD = 8.3407 + 1.546 age (Linear)	0.21	>0.05
Male (n = 103)	20-70	BMD = 206.36 – 1.4572 age (Linear)	0.57	<0.001

Table. 3 Comparison of BMD results and changes measured by QCT in Thai females and ones from other countries

Age groups	Thai				Chinese				American				European		
	N	Mean ± SD	Changes	% Change	N	Mean ± SD	Changes	% Change	N	Mean ± SD	Change	% Changes	Mean ± SD	Change	% Changes
20-29	58	171.9±28.3			44	186.90±28.6*			41	166.70±19.2			159.10±27.6*		
30-39	60	165.5±20.9	-6.4	-3.7%	38	175.81±21.1*	-11.09	-5.9%	120	162.90±25.9	-3.80	-2.3%	158.28±27.6	-0.8	-0.5%
40-49	94	155.1±26.7	-10.4	-6.3%*	46	155.02±26.1	-20.79	-11.8%*	119	151.30±28.9	-11.60	-7.1%*	138.30±27.6*	-20.0	-12.6%*
50-59	72	113.6±30.0	-41.5	-26.8%*	51	118.96±25.7	-36.06	-23.3%*	203	119.50±27.1	-31.80	-21.0%*	108.32±27.6	-30.0	-21.7%*
>60	38	89.4±23.9	-24.2	-21.3%*	59	86.96±27.2	-32.00	-26.9%*	55	94.45±23.0	-25.05	-21.0%*	84.105±27.6	-24.2	-22.4%*

* significant difference at 0.05

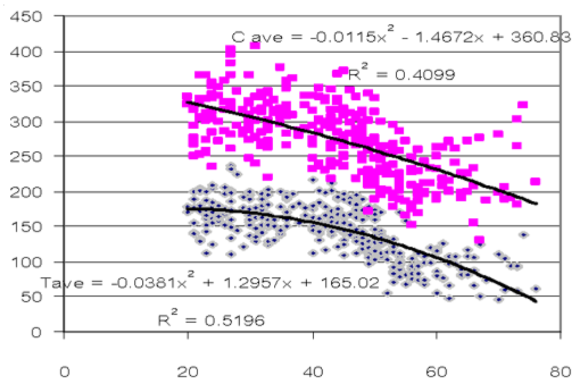

Fig. 3 BMD (Tave and C ave) vs age among females

Thai females have BMD significantly lower than that of Chinese females but not significantly different from that of American and European females. In the 40-49 age range, Thai females' BMD is significantly higher than that of European females. After the age of 50 years, there is no significant difference in BMD among the four groups. The percentage change is not significant going from the 20-29 age range to the next ten-year age range but is significant when advancing to each successive age range thereafter. This finding is similar to that found among Chinese, Americans, and Europeans. Surprisingly, both Thai and Chinese females have a higher peak bone mass and a higher rate of bone loss with age than do the other groups. The relationship between trabecular and cortical bone change with age is shown in Fig. 3. The cortical bone BMD is fitted with a linear regression curve showing that the cortical bone loss is relatively higher in the under-40 age range than in the over-40 range. The authors examined trabecular bone BMD at each lumbar level and grouped the measurements in ten-year age ranges. In the age ranges before the mid-30's, there is no difference in BMD among the lumbar levels. In age ranges after the mid-30s; higher lumbar levels are correlated with higher BMD. (Table 4 and Fig. 4). These findings imply that

Table 4. BMD of each lumbar site categorized by age among female subjects

Age	TL1	TL2	TL3	Tave
20-29	172.55	171.23	172.01	171.93
30-39	166.85	164.19	165.52	165.52
40-49	158.22	153.86	153.20	155.09
50-59	118.58	113.25	108.88	113.57
>60	94.08	90.08	83.90	89.35

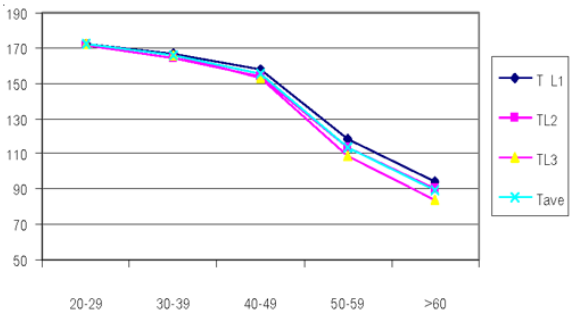

Fig. 4 BMD at each lumbar site categorized by age among females subjects

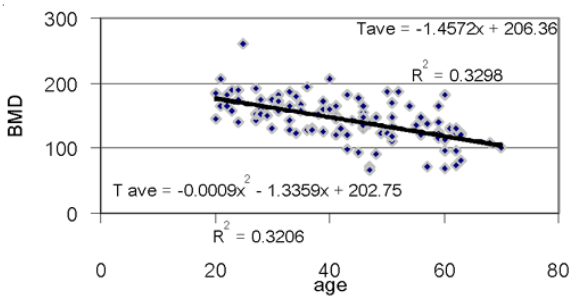

Fig. 5 Tave vs age among male subjects

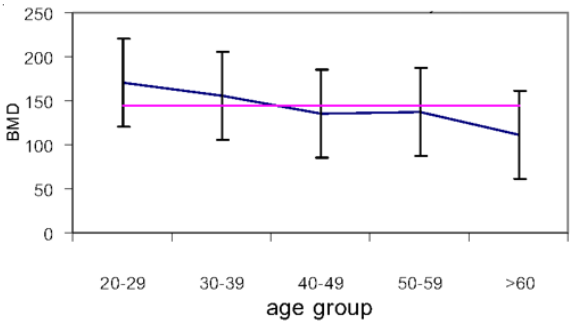

Fig. 6 BMD values in Thai males assessed by QCT

rate of bone loss is much greater in the lower lumbar. For Thai males, the BMD values (Fig. 5, 6) show a higher rate of bone loss than that seen in Thai females in the 20-49 age range, then a slightly increased BMD in the 50-59 age range, and nearly the same rate of bone loss as Thai females in the over-60 age range.

The comparison of Thai males' BMD (Table 5) shows that peak bone mass among Chinese, Europeans, and Thais occurs in the same age range, 20-29 years. Peak bone mass and BMD values in the 30-49 age range are similar between Thai and European males. In older age groups, Thai males have significantly higher BMD values than European males. The percentage change of Thai males BMD is significant in the 20-49 year age range. Moving to the 50-59 age range, the BMD value does not change significantly, but does change significantly once there is a move to the over-60 age range. A period of no significant change in BMD was also seen in the Chinese except that it came earlier (40-49 age range) than in Thai males. The authors could not find this stage of static BMD in the Europeans' data. Fig. 7 demonstrates the relationship between trabecular and cortical bone change with age. The graphic shows little cortical bone loss compared with the higher loss of trabecular bone. The loss of cortical bone seen in the linear regression curve is less than that seen in Thai females.Trabecular bone BMD values at each lumbar level grouped in ten-year age groups show higher values in L3 in the 20-29 age group and lower values for L3 than L1 in the over-60 age group (Fig. 8 and Table 6). The authors calculated a cut-off point for the diagnosis of osteopenia at -1SD from peak bone mass and of osteoporosis at -2.5 SD from peak bone mass. The authors considered a diagnosis of osteopenia and osteoporosis of Thai females when the BMD was below 143.6 mg/cu cm and 101.15 mg/cu cm, re-

Table 5. Comparison of BMD results and changes measured by QCT among Thai males and from other countries

Age groups	Thai				Chinese				European		
	N	Mean ± SD	Change	% change	N	Mean ± SD	Change	% change	Mean ± SD	Change	% change
20-29	21	171.0±27.8			21	174.10±32.27			166.94±26.5		
30-39	22	155.5±22.4	-15.5	-9.08%*	28	155.33±24.70	-18.77	-10.78%	149.81±26.5	-17.1	-10.26%
40-49	25	135.7±33.6	-19.8	-12.71%*	28	148.52±26.09#	-6.81	-4.38%	132.68±26.5	-17.1	-11.43%
50-59	21	137.4±26.8*	1.7	1.22%	33	129.03±23.90#	-19.49	-13.12%	115.53±26.5	-17.2	-12.93%
>60	14	110.3±28.4*	-27.1	-19.75%*	56	106.05±30.10*	-22.98	-17.81%	89.84±26.5	-25.7	-22.24%

* significant difference at 0.05
# The significant difference was observed when compared with European population

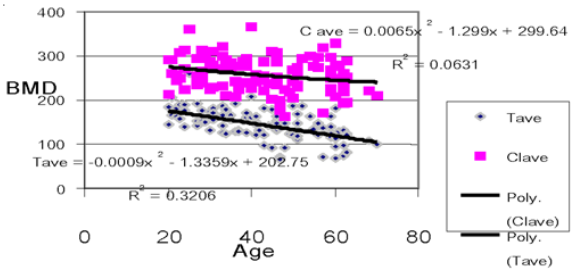

Fig. 7 BMD (Tave and C ave) vs age among males

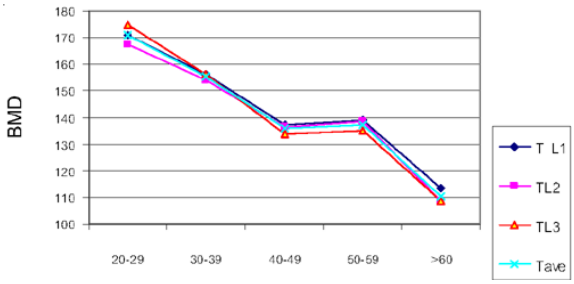

Fig. 8 BMD at each lumbar site categorized by age among male subjects

Table 6. BMD of each lumbar site categorized by age among male subjects

Age	TL1	TL2	TL3	Tave
20-29	171.06	167.32	174.69	171.02
30-39	156.25	154.11	156.11	155.49
40-49	137.08	136.32	133.76	135.72
50-59	138.79	138.44	134.90	137.38
>60	113.36	108.63	108.76	110.25

spectively; and below 143.2 mg/cu cm for Thai male osteopenia and 101.5 mg/ cu cm for osteoporosis.

Discussion

The presented meta-analysis suggests that spinal BMD has the best predictive ability for spine fractures[15]. Trabecular volume is more heterogeneously distributed inside young human lumbar vertebrae in the vertical direction than inside old vertebrae[16]. Therefore, measurement should ideally encompass the entire vertebrae. It is not realistic to do this with classical histomorphometry, but it may be possible in the future with microcomputed tomography if the development of scanners continues, so that larger specimens can also be investigated at high resolution (i.e voxel size < 10 um). Nowadays, QCT is generally performed in the central part of the vertebral body in both clinical and preclinical investigation. Relatively high peak bone mass in Thai females is explained that Thais have a vitamin D receptor (VDR) gene of the bb genotype in as high as 85% of population[17]. This differs from the Caucasian but is similar to the Japanese population. The aa and bb genotypes promote calcium absorption from the intestine and a higher response to vitamin D analog than do the AA, Aa, BB and Bb genotypes[18]. The stage of static BMD found in Thai males' and Chinese males' BMD, may result from some common Asian males' life styles. The authors compared Thais' spinal BMD between the present QCT study and the DXA study from Limpaphayom[19]. There are two major differences. First, peak bone mass of Thai females in the presented QCT study is earlier than in the DXA study. Second, BMD from QCT of higher lumbar levels is higher than in the lower levels - the opposite of what is the case with DXA. This reflects the different timing of bone maturation in trabecular and cortical bone[12] and different bone compartment measurement. Peak bone maturation seems to be reached earlier in trabecular bone than in cortical bone and is detected better by QCT than DXA. DXA measures an integral of cortex and trabecular bone whereas QCT measures the central trabecular portion of the vertebral body. Integral spinal measurement represents approximately 60-80% cortical bone, which is less liable than trabecular bone[10]. Lang et al[14] noted that cortical and trabecular bone have different rates of age- and menopause-related decline at different skeletal sites. This may explain the difference in BMD variation by lumbar level between the authors' and Limpaphayom's study, but it does not explain the relationship between Thais cortical and trabecular bone from the present study. Loss of cortical bone in Thai females is more rapid than trabecular bone loss in the under-40 age range. In the over-40 range, the rate of female cortical bone loss is the same rate as trabecular bone loss. For males in this age range, the rate of cortical bone loss is less than trabecular bone loss.

The BMD of Thai females decrease more than that of other ethnic groups after the 40-49 year age range. This is a reflection of the life style of Thai women, who think of themselves as elderly, deny themselves physical activity, and content themselves with the role of housewife. This research is a cross sectional study to discern the trend, and more precisely the value, of the BMD of Thai females. It will be worthwhile to follow the BMD of the subjects in the 20-29 year age

group at 5-year intervals and perform a longitudinal study of these subjects.

Conclusion

From this research we have developed a cut-off point of osteopenia at 143.6 mg/ cucm and osteoporosis at 101.15 mg/ cucm for Thai females; 143.2 mg/ cucm and 101.5 mg/ cucm, respectively for Thai males. The relative higher peak bone mass in Thais should be maintained. In age groups with a high bone loss rate, especially among females, some interventions should be put in place to decrease the rate of bone loss.

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ความหนาแน่นของเนื้อกระดูกสันหลังในคนไทย โดยเครื่องเอกซเรย์คอมพิวเตอร์: เปรียบเทียบกับค่าความหนาแน่นของเนื้อกระดูกสันหลังของชาวตะวันตก

สุชาดา ฮุนพงษ์สิมานนท์, มนตรี สันติภาพมณฑล, มัทนา จันทนา

การศึกษานี้เพื่อหาค่าความหนาแน่นของเนื้อกระดูกสันหลังในคนไทยด้วย QCT โดยสัมพันธ์กับอายุและเพศ เพื่อเปรียบเทียบกับค่าความหนาแน่นของเนื้อกระดูกสันหลังของชาวตะวันตก ผู้รายงานได้ทำการศึกษาในคนไทยที่มีสุขภาพดีจำนวน 425 ราย อายุ 20-76 ปี (เป็นผู้หญิง 322 ราย อายุเฉลี่ย 43.4 ปี; เป็นผู้ชาย 103 ราย อายุเฉลี่ย 42.8 ปี พบว่าความหนาแน่นของเนื้อกระดูกสันหลังสูงที่สุดในช่วงอายุ 20-29 ปี ทั้งในหญิงและชาย ในผู้หญิงมีค่าเฉลี่ยเท่ากับ 171.9 มก.ต่อ ลบ.ซม. และในผู้ชายเท่ากับ 171.0 มก.ต่อ ลบ.ซม. และค่านี้จะลดลงเมื่ออายุมากขึ้น อัตราการสูญเสียความหนาแน่นของเนื้อกระดูกในผู้ชายจะสูงกว่าผู้หญิงจนถึงช่วงอายุ 40-49 ปี และในช่วงอายุ 50-59 ปี จะคงที่ ขณะที่การสูญเสียความหนาแน่นของเนื้อกระดูกในผู้หญิงจะมากที่สุดในช่วงอายุนี้ หลังจากอายุ 55 ปี พบว่าทั้งหญิงและชายจะมีการสูญเสียความหนาแน่นของเนื้อกระดูกจากอายุที่เพิ่มขึ้น เมื่อเปรียบเทียบกับชาวตะวันตกพบว่าช่วงอายุที่มีความหนาแน่นของเนื้อกระดูกสูงสุดเหมือนกัน แต่ผู้หญิงไทยมีค่าความหนาแน่นของเนื้อกระดูกสูงสุดมากกว่าผู้หญิงชาวตะวันตกแต่ค่านี้ไม่มีความแตกต่างในผู้ชายไทยกับผู้ชายตะวันตก สำหรับช่วงอายุ 50 ปีขึ้นไป ความหนาแน่นของเนื้อกระดูกในผู้ชายไทยจะสูงกว่าชาวตะวันตก

จากการศึกษาได้ค่าความหนาแน่นของเนื้อกระดูกสันหลังในผู้หญิงคนไทยที่บ่งบอกว่าเป็นกระดูกบาง (Osteopenia) มีค่าน้อยกว่า 143.6 มก.ต่อ ลบ.ซม. และกระดูกพรุน (Osteoporosis) มีค่าน้อยกว่า 101.15 มก. ต่อ ลบ.ซม. สำหรับผู้ชายไทยมีค่าน้อยกว่า 143.2 มก. ต่อ ลบ.ซม. ในกระดูกบางและน้อยกว่า 101.5 มก. ต่อ ลบ.ซม. ในกระดูกพรุน