Quantitative Morphometric Analysis of Vertebral Fracture Severity in Healthy Thai (Women and Men)

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The vertebral morphometry and severity of fracture were studied in normal healthy Thais (602 women and 74 men) Their mean (±SD) age was 41.4 (± 8.7) years, ranging from 20-81 years. A standard lateral thoraco-lumbar (T-L) spine radiograph was done by centering the X-ray at L_1. Vertebral heights (anterior: Ha, middle: Hm and posterior: Hp), disc height (Hd) and 4 vertebral ratios (anterior wedging: Ha/Hp, central wedging: Hm/Hp, vertebral body index: Hm/Hd and spine score: Hm/Ha) of T_{10}-L_3 were assessed. Degree of severity of anterior and central wedging fracture was derived to mild, moderate and severe fracture ratios (0.80-0.89, 0.70-0.79 and < 0.70, respectively). In Thai females, anterior and central wedging significantly changed at T_{11} after the 40-49 age group, while spine score markedly declined at L_2-L_3 after the 30-39 age group. The change of vertebral body index was not seen. The overall (T_{10}-L_3) mean of all ratios of women aged < 50 years were more than that of those aged ≥ 50 years ($p< 0.05$). No statistical change of the above ratios was seen at any levels of the spine in males ($p> 0.05$). The prevalence of mild and moderate degree of anterior vertebral fracture was 22.76% and 0.50% in females and 25.68 and 0% in males. Percentage of mild and moderate degree of central vertebral fracture was 66.61 and 1.00 in females and 68.92 and 1.35 in males. The prevalence of anterior and central compression fracture in females and males who were aged ≥50 years were higher than those aged < 50 years. No severe degree of anterior and central vertebral fracture was detected in both sexes. 407 young adults mean (20-40 years) of the 4 ratios at T_{10}-L_3 were also surveyed and calculated for Thai reference databases. The prevalence of the 4 ratios below young adult mean 1, 1.5, 2, 2.5 and 3 SDs in males were greater than in females. In the older age groups, the percentage of females and males who had a mean ratio below young adult mean was much more than that in the younger age groups. In screening of spinal osteoporosis, the authors suggested that the age after 40 years of populations should be x-rayed and spinal radiograph should have an observed focus at T_{11}, L_2 and L_3.

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Although bone mineral densities (BMDs) were significantly lower with increasing radiological osteopenia grades ($p<0.001$) and remained lower after the adjustment of age and body mass index ($P<0.001$), conventional spinal radiography is a common investigation for patients with back pain[1]. Clinical vertebral fractures are associated with significant morbidity[2,3]. However, technique variations (positioning and exposure techniques), a high degree of image distortion and variation in the qualitative assessment of deformity among experienced radiologists reflect uncertainties. Development of quantitative analysis by measurement of the posterior, middle and anterior heights of the vertebra on lateral spine radiographs, can aid qualitative evaluation by comparing vertebral height ratios (anterior/posterior or mid/posterior)[4]. A fracture was considered to be present if the anterior or central height was decreased by 2 mm or more from the posterior height. Degree of severity of vertebral fracture was derived to mild, moderate and severe fracture ratios (0.80-0.89, 0.70-0.79 and < 0.70, respectively). Anterior wedging is present with increased frequency in both the mid-thoracic spine[5] and at the thoraco-lumbar junction[5,6]. Central compression fracture occurs most

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commonly at L_1-L_4 but they can occur at any spinal level below T_2[5]. Mechanical testing has shown that vertebral resistance to collapse is the highest in the lumbar spine. The thicker lumbar vertebral cortex may resist anterior wedging and that loss of trabecular bone results instead of central compression as a second factor, the normal lumbar lordosis may relatively protect the lumbar vertebra from anterior wedging forces [5,7]. In this prospective study the authors investigated the prevalence of vertebral deformities in the thoraco-lumbar spine (T_{10}-L_3). The x-ray exposure was adjusted until the morphometry of each vertebra could be seen and measured on one radiograph. Age distribution of vertebral height ratios (anterior wedging, central wedging, lumbar spine score and vertebral body index, were observed in healthy Thais. Degree of severity of vertebral fracture on lateral T-L spine radiographs was examined. For the standardization of Thai reference values, young adults (20-40 years) mean of vertebral height ratios were also calculated. The normal mean of the ratios were valuable value of any geographic area for diagnosis of vertebral fracture severity because it depended on life style and race[8]. The use of different databases has recently shown they account for the significant differences in the number of patients with the diagnosis of osteoporosis[9]. Vertebral deformities cause substantial pain, disability or loss of height only if vertebral height ratios fall 4 SD below the normal mean [10].

The prevalence of osteoporosis, if defined as t score <-2.5 is highly dependent on the sampling of the reference population of young adult women and also on the choice of skeletal site[11]. Eastell, et al defined the vertebral deformity by using 3 SD of any one of the four vertebral height ratios : Ha/Hp, Hm/Hp, Hp/Hp-above and Hp/Hp-below deviated below the reference mean value[4]. So studies on bone mineral density or morphometry of vertebral spine in healthy young adult women are needed.

Material and Method

1,813 ambulated volunteers were interviewed for searching the factors affecting bone mass. Non-fasting serum calcium, phosphate, alkaline phosphatase were measured by routine methods. Of these subjects, 956 (52.73%) had a relevant medical disorder (alcohol abuse, cigarette smoking, caffeine ingestion over 6 glasses per day, hypogonadism, glucocarticoid therapy, 152 (8.38%) received a surgical procedure (thyroidectomy, parathyroidectomy, oophorectomy) and 29 (1.59%) had a blood examined disorder. 602 healthy females and 74 healthy males were included in a prospective study to evaluate the morphometry of vertebral spine and the prevalence of vertebral fracture in normal Thais. Their ages ranged from 20 to 81 years (mean±SD = 41.4±8.7 years). Standard lateral thoracolumbar (T-L) X-ray radiograph was taken with a tube-to-film distance of 101.6 cm and was centered at L1. Six points were marked for each vertebral body of T_{10}-L_3. Manual measurements of vertebral heights and disc height were performed by using a vernier caliper by a trained single operator under the supervision of a radiologist and orthopedist. Morphometric data of anterior wedging, central wedging, vertebral body index and spine score were stored and calculated by SPSS-PC (version 7.5) and Microsoft Excel software. Intraobserver error of the measurement was tested in a random sample of 20 lateral spine radiographs. The coefficient of variations was 0.169, 0.243, 0.545 and 0.666% for Ha, Hm, Hp and Hd, respectively. The effect of age on vertebral dimensions was assessed by dividing the subjects into six groups depending on age (20-29, 30-39, 40-49, 50-59, 60-69 and > 70 years). Differences between the mean of 4 ratios in <50 and ≥50 years age groups in females were compared by using student's t test. The presence of severity of vertebral fracture in each decade were classified to mild, moderate and severe. Percentage of anterior and central compression fracture of subjects aged under and above 50 years was also computed. Distribution of the 4 ratios by age groups at each spine level were plotted to show the age related changes of vertebral deformity. Reference data of the 4 vertebral height ratios (mean and standard deviation) were calculated for the young adult group. The prevalence of subjects who had ratios deviating below 1, 1.5, 2, 2.5 and 3 SDs were evaluated.

Results

602 females and 74 males were evaluated for morphometry of the 10th thoracic to 3rd lumbar spine (T_{10}-L_3). Mean ± SD of anterior wedging, central wedging, vertebral body index and spine score in each decade of age in both sexes were computed and plotted as shown in Fig. 1. In the older age groups, the percentage of females and males who had a mean ratio below young adult mean was much more than that in younger age groups. In females, anterior and central wedging significantly changed at T_{11} in the 40-49 age group, while spine score markedly declined at L_2-L_3 in the 30-39 age group(Fig. 1a, b, d). The change of vertebral body index was not seen (Fig. 1c). Mean of

Table 1. Mean(±SD) value of anterior wedging, central wedging, vertebral body index and spine score in women 414 cases aged <50 and (188 cases)aged ≥50 years

Spine level	Age (years)	Anterior wedging Mean (±SD)	p	Central wedging Mean	p	Vertebral body index Mean	p	Spine score Mean	p
T_{10}	<50	0.9152	<0.01	0.8996	<0.01	4.1687	<0.01	94.0827	0.328
	≥50	0.8971		0.8977		3.7357		93.5648	
T_{11}	<50	0.8740	<0.01	0.8836	<0.01	3.8436	0.02	94.9441	<0.01
	≥50	0.8074		0.8404		3.8205		93.1620	
T_{12}	<50	0.9367	<0.01	0.8842	<0.01	3.6745	<0.01	95.0629	<0.01
	≥50	0.9167		0.8698		3.4865		93.6448	
L_1	<50	0.9412	<0.01	0.8986	0.002	3.4661	<0.01	95.7229	0.037
	≥50	0.9202		0.8862		3.4591		95.1619	
L_2	<50	0.9720	0.094	0.8766	0.048	3.2954	<0.01	92.5632	<0.01
	≥50	0.9698		0.8669		3.0881		90.0297	
L_3	<50	0.9830	<0.01	0.8962	<0.01	2.9312	<0.01	91.9861	<0.01
	≥50	0.9706		0.8777		2.7123		87.8062	
T_{10}-L_3	<50	0.9370	<0.01	0.8898	<0.01	3.4949	0.016	94.0603	<0.01
	≥50	0.9136		0.8731		3.4520		92.2283	

Table 2. Prevalence(%) of anterior wedging fracture by sex and age groups

Age groups (years)	Severity of fracture: Mild degree females	Mild degree males	Moderate degree females	Moderate degree males
20-29	15.71	25.00	1.43	0.00
30-39	14.06	14.29	0.00	0.00
40-49	19.23	27.27	0.00	0.00
50-59	34.11	25.00	0.00	0.00
60-69	40.91	50.00	2.27	0.00
>70	33.33	0.00	6.67	0.00
Total	22.76	25.68	0.50	0.00

Table 3. Prevalence (%) of central wedging fracture by sex and age groups

Age groups (years)	Severity of fracture: Mild degree females	Mild degree males	Moderate degree females	Moderate degree males
20-29	74.29	37.50	1.43	0.00
30-39	69.53	71.43	0.00	0.00
40-49	53.37	77.27	0.48	0.00
50-59	77.52	62.50	0.00	6.25
60-69	77.27	80.00	4.55	0.00
>70	60.00	75.00	13.33	0.00
Total	66.61	68.92	1.00	1.35

Table 4. Percentage (%) of anterior & central compression fracture in healthy Thai aged <50 and ≥50 years

Sex	Age groups (years)	n	Anterior compression fracture: mild	moderate	severe	Central compression fracture: mild	moderate	severe
Females	<50	414	16.91	0.24	0.00	62.32	0.48	0.00
	≥50	188	35.64	1.06	0.00	76.06	2.13	0.00
Males	<50	44	22.73	0.00	0.00	68.18	0.00	0.00
	≥50	30	30.00	0.00	0.00	70.00	3.33	0.00

the 4 ratios at each vertebral levels <50 and ≥50 years were significantly different ($p<0.05$) except mean of spine score at T_{10} ($p=0.328$) and anterior wedging at L_2 ($p=0.094$) as shown in Table 1. However, the overall mean of T_{10}-L_3 of women aged <50 years were more than those aged ≥50 years ($p<0.05$). No statistical change of the above ratios was seen at any levels of spine in males ($p>0.05$) as shown in Fig. 1e-h. Prevalence of severity of anterior wedging fracture (Table 2) and central wedging fracture (Table 3) in both sexes are shown. The results showed that the prevalence of mild and moderate degree of anterior vertebral fracture were 22.76% and 0.50% in females and 25.68 and 0% in males. Percentage of mild and moderate degree of central vertebral fracture was 66.61 and 1.00 in females and 68.92 and 1.35 in males. The prevalence of anterior and central compression fracture in females and males who were aged ≥50 years were higher than those aged <50 years (Table 4). No severe degree of anterior and central vertebral fracture was detected in both sexes. Percentage of central wedging fracture was more than anterior wedging fracture. 407 young adult mean (20-

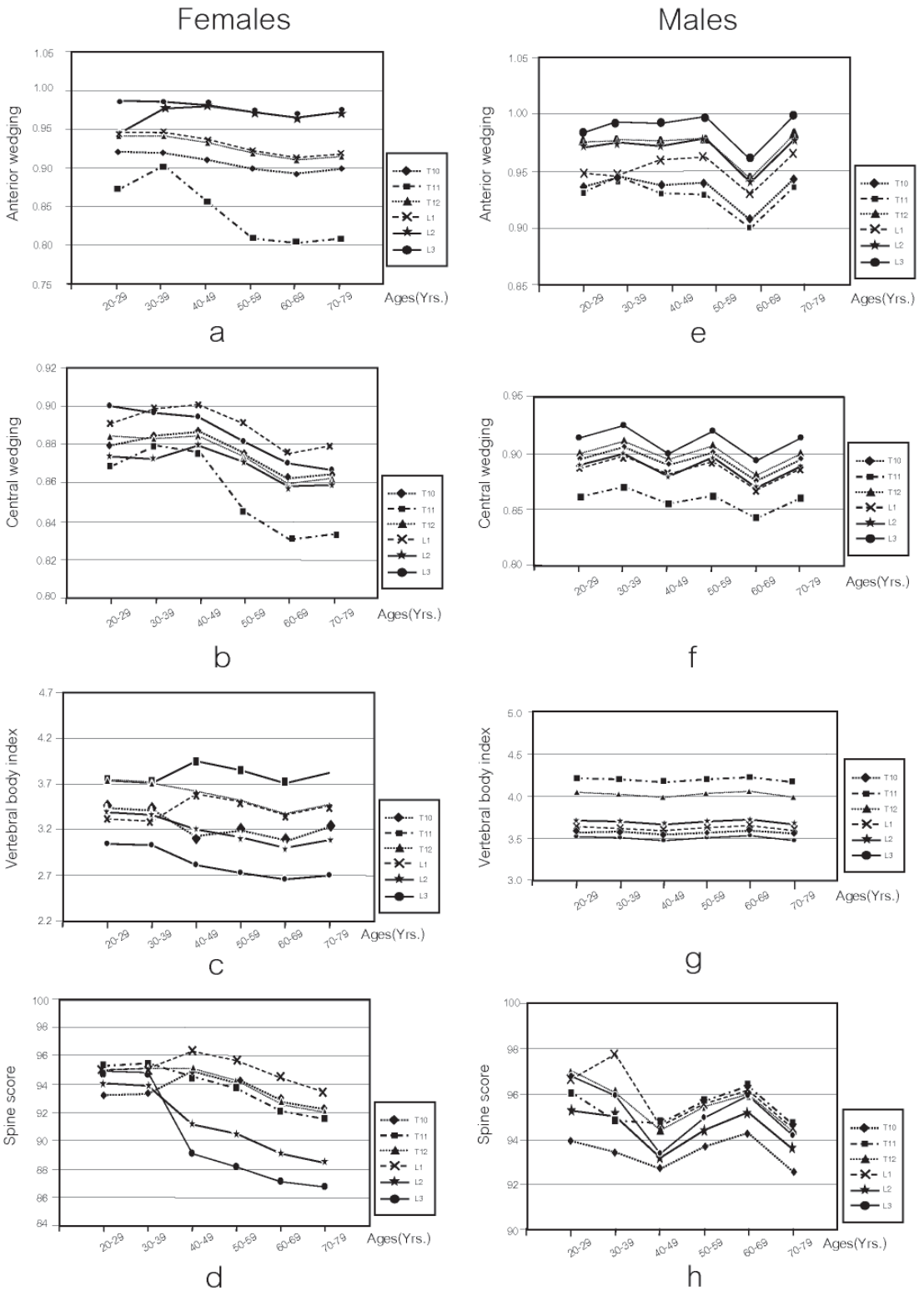

Fig. 1 Age distribution of 4 vertebral height ratios in females and males: anterior wedging (a, e) central wedging (b, f) vertebral body index (c, g) and spine score (d, h)

40 years) of the 4 ratios at T_{10}-L_3 were also surveyed and calculated as shown in Table 5. The prevalence of the ratios below young adult mean 1, 1.5, 2, 2.5 and 3 SDs in males were greater than in females (Table 6).

Discussion

In many areas, bone densitometry is not yet readily available and in this situation conventional spine x-rays are often assessed for osteopenia[1]. The majority of fractures occur in the mid thoracic and lower thoracic / upper lumbar spine, although lumbar spine x-rays were not performed unless thoracic deformity was identified[12]. Spinal fracture is the major complication of osteoporosis. To prevent the morbidity or disability from spinal fracture, a screening program should be established. In this present survey, a lateral radiograph of T_{10}-L_3 spine was taken in one film. The exposure was adjusted until the edges and the center of each spinal body and intervertebral spaces could be measured. The authors evaluated the morphometry of vertebral spine by using the vertebral height ratio instead of vertebral height. So normal variation in vertebral shape including a high degree of image distortion due to the cone beam geometry of the imaging system and the difference in focal spot location on each film were eliminated.

In females, anterior wedging (Ha/Hp) and vertebral body index (åHm/åHd) declined slowly from age 20 (Fig.1a,c) while central wedging (Hm/Hp) and spine score [(Hm/Ha)x100] markedly changed after the age of 49 and 39 years (Fig.1b,d). The average ratio of anterior wedging, central wedging, vertebral body index and spine score at T_{10}-L_3 in those aged $\geq$ 50 years were significantly lower than the average value in age <50 years (Table 1). This evidence supported that the age of osteoporotic study usually started at 50[2,13].

Vertebral deformity occurrence increased with age in both European sexes[14]. In the present study, the prevalence of anterior and central compression fracture increased dominantly after the age of 50 in Thai females (Table 4) and the prevalence of the 4 ratios below young adult mean 1, 1.5, 2, 2.5 and 3 SDs in males were greater than in females (Table 6). The total risk of vertebral deformity in men was greater than in women (Table 2 and 3). There is a possibility that men were exposed to greater trauma during their working life and that these deformities are therefore "traumatic"[15,16].

Women aged more than 50 years had a 2 times higher risk of spinal compression fracture than women aged less than 50 years (Table 4). Movement in daily activity is a warning for prevention of spinal compression in older women.

Table 5. Young adult mean (20-40 years) of anterior wedging, central wedging, vertebral body index and spine score at T_{10}-L_3 (N=407)

	T_{10}		T_{11}		T_{12}		L_1		L_2		L_3		T_{10}-L_3	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Anterior wedging	0.9150	0.0380	0.8738	0.0536	0.9365	0.0383	0.9410	0.0383	0.9724	0.0438	0.9828	0.0405	0.9369	0.0395
Central wedging	0.8997	0.0316	0.8907	0.0571	0.8840	0.0318	0.8987	0.0294	0.8764	0.0311	0.8960	0.0315	0.8909	0.0316
Vertebral body index	3.7734	0.7020	3.8408	0.5004	3.6682	0.4689	3.4537	0.4621	3.2874	0.4251	2.9245	0.3823	3.4913	0.4459
Spine score	94.1010	2.8767	94.9371	2.7772	95.0644	2.8392	95.7315	2.8102	92.5186	3.2159	91.9252	4.3043	94.0462	2.6844

Table 6. Prevalence (%) of vertebral fracture using difference cutoff criteria (SDs below young adult mean) in females and males

SDs below young adult mean	Anterior wedging		Central wedging		Vertebral body index		Spine score	
	F	M	F	M	F	M	F	M
1	10.46	13.51	15.45	16.22	5.98	13.51	9.14	9.76
1.5	7.64	12.16	9.14	9.46	4.82	9.46	6.15	6.41
2	6.15	10.81	8.47	10.81	3.16	4.23	6.15	6.70
2.5	4.15	5.41	4.98	5.41	2.32	3.80	4.49	5.35
3	1.99	2.70	2.33	2.70	1.33	2.37	2.16	2.76

An apparent increase in the prevalence of central compression fracture was higher than that of anterior compression fracture in all age groups of both sexes (Table 2, 3 and 4). It indicated that the mid point of the vertebrae was compressed more than the anterior. Trabecular bone was mostly confined at the mid area of the vertebrae and had possibly lower bone mass than the cortical bone.

The heterogeneity in risk of deformity appeared to be greater in osteoporotic research centers than the sexes[14]. This suggested that although factors related to estrogen deficiency (such as menopausal age and gonadal status) play a key role in the pathogenesis of vertebral osteoporosis[17,18], they appear to be less important than environmental or genetic factors[14]. The normal mean of bone status in different geographic areas should be surveyed because it is used as a cutting point for osteoporosis classification. The SDs deviated from the normal mean were observed by some authors. Vertebral deformities cause substantial pain, disability of loss of height only if vertebral height ratios fall 4 SD below the normal mean[19]. Patients with spine fracture have BMD that is –3SD below the level in young normal patients and –1 SD below the level in age-matched patients[20]. In the present report, the authors measured the 4 vertebral height ratios in 407 healthy young adults (20-40 years), the reference young adult mean of the 4 ratios at T_{10}-L_3 were calculated as shown in Table 5. The use of reference databases to define severity of vertebral fracture may result in a highly different prevalence rate in a given population depending on the reference population. Individual populations should use their own reference range of vertebral height ratios to avoid misdiagnosis of moderate and severe degree of vertebral fracture by quantitative analysis.

In clinical practice, spinal radiography and bone densitometry should be regarded as complementary rather than alternative diagnostic procedures. The former assesses bone structure including trabeculations and vertebral deformities. The latter provides information on bone mineral content which is independently associated with fracture risk. However, in many areas bone densitometry is not yet readily available and in this situation conventional spine X-rays are often assessed for osteopenia and reported as such[1]. Since the principle clinical aim in manifest osteoporosis is the prevention of further fractures, quantitative radiological methods performed in addition to densitometry may be of value in management, including grading and monitoring of the progress of the disease[13]. In screening of spinal osteoporosis, the authors suggested that populations aged more than 40 years should be x-rayed and spinal radiograph should be observed focused at T_{11}, L_2 and L_3.

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การวิเคราะห์รูปร่างของกระดูกสันหลังเพื่อประเมินความรุนแรงของกระดูกสันหลังหักในคนไทยปกติ

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ได้ทำการศึกษารูปร่างและความรุนแรงของกระดูกสันหลังหักในคนไทยปกติ เป็นเพศหญิง 602 คน และ ชาย 74 คน ช่วงอายุ 20-81 ปี อายุเฉลี่ย 41.4 (±8.7 ปี) โดยทำการถ่ายภาพเอกซเรย์กระดูกสันหลังส่วนอกและเอว (T-L) ท่าด้านข้าง กึ่งกลางลำแสงลงที่ L1 วิเคราะห์รูปร่างโดยวัดความสูงของ T10-L3 (ส่วนสูงด้านหน้า: Ha, ส่วนสูงตรงกลาง: Hm และส่วนสูงด้านหลัง: Hp) ความสูงของหมอนรองกระดูก (Hd) และอัตราส่วนของส่วนสูงต่าง ๆ 4 ค่า คือ anterior wedging: Ha/Hp, central wedging: Hm/Hp, vertebral body index: Hm/Hd และ spine score: Hm/Ha ระดับความรุนแรงของกระดูกสันหลังหักแบ่งเป็น 3 ระดับ คือ ต่ำ ปานกลาง และรุนแรง (ค่า anterior wedging และ central wedging เท่ากับ 0.80-0.89, 0.70-0.79 และ <0.70 ตามลำดับ) ในเพศหญิง anterior wedging และ central wedging ลดลงอย่างเด่นชัดที่ T11 หลังจากกลุ่มอายุ 40-49ปี ส่วน spine score ลดลงชัดเจนที่ L2-L3 หลังจากกลุ่มอายุ 30-39 ปี ไม่พบการเปลี่ยนแปลงตามอายุของ vertebral body index ในผู้หญิงอายุน้อยกว่า 50 ปี พบค่าเฉลี่ยของอัตราส่วนทั้ง 4 ค่าของกระดูกสันหลังทุกระดับ (T10-L3) สูงกว่าผู้หญิงอายุมากกว่าหรือเท่ากับ 50 ปี (p<0.05) สำหรับเพศชาย ไม่พบการเปลี่ยนแปลงตามอายุของค่าอัตราส่วนทั้งสี่ในกระดูกสันหลังทุกระดับ (p>0.05) กระดูกสันหลังหักระดับต่ำและปานกลางตรง anterior wedging ในผู้หญิงมีค่า 22.76% และ 0.50% ในผู้ชายมีค่า 25.68% และ 0% ตรง central wedging ในผู้หญิงมีค่า 66.61% และ 1.00% ในผู้ชายมีค่า 68.92% และ 1.35% ผู้ที่มีอายุมากกว่าหรือเท่ากับ 50 ปี พบอุบัติการณ์เกิดกระดูกสันหลังหักระดับต่ำและปานกลาง มากกว่าผู้ที่อายุน้อยกว่า 50 ปี โดยไม่พบกระดูกสันหลังหักระดับรุนแรงในทั้งสองเพศ นอกจากนี้ยังได้คำนวณค่าเฉลี่ยของอัตราส่วนทั้งสี่ที่ T10-L3 ในวัยหนุ่มสาวเพื่อใช้เป็นค่าอ้างอิง อายุที่มากขึ้นจะพบจำนวนผู้ที่มีค่าอัตราส่วนทั้งสี่อยู่ต่ำกว่าค่าอ้างอิงเพิ่มขึ้น ในการตรวจกรองโรคกระดูกพรุนด้วยการเอกซเรย์กระดูกสันหลังควรทำในประชาชนที่ มีอายุมากกว่า 40 ปี และควรศึกษารูปร่างของกระดูกสันหลังอย่างละเอียดที่ T11 , L2 และ L3