

The study of bone mass measurement by clavicle radiogrammetry in a comparison to the dual energy x-ray absorptiometry examination

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ABSTRACT

Background: Clavicle radiogrammetry test related to chest radiography has been found to be useful in evaluation of osteoporosis. The diagnosis of osteoporosis was based on the measurement of bone mineral density (BMD) with dual energy x-ray absorptiometry.

Objectives: The aim of this study was to evaluate bone mass measurement using clavicle radiograms to differentiate the goal standards related to the dual energy x-ray absorptiometry methods.

Materials and methods: The population sample consisted of a 100 healthy Thai adult volunteers, (50 women, 50 men) aged from 24 to 76 years. The study subjects were divided as normal bone mass group, T-score ≥ -1.0 and the low bone mass group, T-score ≤ -1.0 . Subsequently, posteroanterior (PA) chest radiographs were taken. Measurements of the clavicle radiograms were evaluated, and the images at the midshaft of both clavicles were calculated. An independent t-test was used to examine the differences between the normal and the low bone mass of each gender and two separate BMD sites. The confidence interval was 95% at level of significance 0.05. Pearson's correlation was used to measure the strength and direction of linear relationship between the bone mass measurement using the dual energy x-ray absorptiometry (DEXA) test and clavicle radiogrammetry test.

Results: The results showed 18 women and 28 men maintained a normal BMD, while 32 women and 22 men had low bone mass density. The average clavicle thickness measurements of the normal bone mass of the women group were lower than the normal bone mass measurements of men. Conversely, the low bone groups of women measurements were higher than low bone mass in the men's group. A greater diminishing of cortical thickness of clavicle was found in the low bone mass than normal group for both genders. The average cortical thickness of clavicle in the low bone mass of women decreased by 17.8% (5.31 mm/6.46 mm) compared to normal women, while in men, which were fewer, 16.13% (7.07 mm/8.43 mm) between groups, respectively. The average measurements of the clavicle periosteal width and combined cortical thickness of clavicle showed a positive correlation with BMD, whereas, the clavicle endosteal width showed a negative correlation with BMD.

Conclusion: Using the radiogrammetric method to measure the clavicle cortex thickness on the chest x-ray images showed a gradual thinning of the cortex with aging. By comparison, the measurements of clavicle cortex thickness showed a moderate relationship with BMD performed by DEXA in the assessment of osteoporosis.

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Introduction

Osteoporosis, a global epidemic, has a major impact on the quality of life of individuals bone fragility. A decrease in bone strength and the changes in the bone structure causes suffering for individual of all ages. This is particularly relevant when referring to the elderly. Especially in elderly women are more likely to suffer from osteoporosis than men.¹ Previous study related to Thai people has highlighted a higher incidence of cases diagnosed with osteoporosis (1 in 3 women and 1 in 5 men).² The measurement of bone mineral density (BMD) with dual energy x-ray absorptiometry (DEXA) revealed osteoporosis occurred of 13.6% in the hips and 19.8% in the lower lumbar of the spine. During the process of bone growth and development, the amount of mineralised bone increases until it reaches peak bone mass which occurs around the late 20 sec or early 30 sec. Peak bone mass highest density normally transpires as a result of genetics, exercise, nutrition, and hormone levels. A slowly decline of bone mineral density occurs at which of hormone changes and aging. Peak bone mass is higher in men than women, it also higher amongst Black ethnicities compared to Asians or Whites. In general, the BMD is the highest during adolescent between the age of 30-35 years.³ Men have a higher BMD than women around 15% to 20%. As the age increases, bone density continues to decrease slowly. The rate of bone loss is about 0.5% to 1% per year.⁴⁻⁶

According to WHO criteria, the diagnosis of osteoporosis is based on the measurement of the BMD using DEXA. The result of bone density test is evaluated according to the T-score value. T-scores value indicate the number that compared a person's bone density with those of healthy young adult of the same race, ethnicity, and gender. In this work, the T-score values are calculated based on a peak BMD reference among Asian population (Japanese database) per individuals related to gender identity. When a T-score value registers below or equal to -2.5, it is diagnosed as osteoporosis; a T-score value between -1.0 and -2.5 is diagnosed as osteopenia; a T-score greater than -1.0 is considered normal bone density.^{7,8}

Clavicle radiograms using a chest x-ray image has been found to be useful and feasible in evaluation of osteoporosis.⁹ A simple radiogrammetric method, image on digital radiographs, has achieved a good result related to evaluation osteoporosis compared to the DEXA scan. The radiograms offered a statistically significant correlation regarding the risk assessment of osteoporosis in the elderly population. Findings show a sensitivity level of 88.8% and 95.6%; specificity of 89.6% and 90.9%; positive predictive value of 88.8% and 95.6%; and negative predictive values of 89.6% and 90.9%, respectively. This method is supported by works performed by Delimayanti who demonstrated that the thoracic radiographic feature analysis strongly correlates with the bone density measurements using the DEXA in the assessment of osteoporosis. The method proposed in this study indicates the diagnostic test has a sensitivity of 100%, specificity of 90%, and accuracy of 97.83%.¹⁰

Studying the bone health in the local population is relevant for osteoporosis prevention. In a study conducted by Kruger *et al.* reported that the BMD T-score are different

amongst the seven Asian countries. The highest poor bone health was observed in Vietnam for people aged 70 years, while in Thailand, the highest level of bone loss was observed in individual over 80 years of age.¹¹ The obvious gap in the highest level of bone loss between the two nation is concerning. Because of ethnic heterogeneity, the degree of bone loss and bone change are different. The objective of this study was to evaluate bone mass measurements on the clavicle radiograms, while providing a comparative overview of dual energy x-ray absorptiometry. We hypothesized that the distribution of bone mineral density will be different between countries. Comparison of bone density measurement between techniques will help to spot bone structure changes such as in size, thickness, or texture for Thai adults who display no symptom. However, it is recommended that individuals should monitor and follow-up bone health regularly, which would afford their medical care providers the chance to offer treatments that can reduce the severity of osteoporosis.

Materials and methods

A quantitative analysis method has been adopted in the study. This work was based on the analytical research to determine the relationship between data performed by the DEXA and the clavicle radiograms. The study was approved by the institutional review board of Naresuan university (IRB No. P10150/64). Each participant agreed to participate in the study and gave written informed consent. Recruitment and selection of participants was performed from December 2021 to April 2022 at the Regional Health Promotion Center 2, Phitsanulok Province, Thailand. All 100 participants (50 women, 50 men) were healthy Thai adults between the age of 24 and 76 years old, who live in Phitsanulok Province. Subjects with bone disorders, abnormal bone metabolism, and abnormal shape of clavicle were excluded from the study. As shown in Figure 1, information related to the parameters of the experimental procedures were presented. The BMD measurement of the lumbar vertebrae L1-L4 region and the one hip (left or right) were determined using DEXA (Hologic Discovery Wi, QDR series, USA). The BMD values were measured and reported using DEXA software at two areas of the lumbar vertebrae L1-L4 region and the one hip. According to WHO's classification, a T-score values measurement of the BMD was performed, the study subjects were divided as follows: (1) normal bone mass for those with T-score ≥ -1.0 , n=46 (women=18, men=28) and (2) a low bone mass and poor bone quality (combining osteopenia and osteoporosis) for those with a T-score less than -1.0, n=54 (women=32, men=22). Subsequently, a standard digital chest posterior-to-anterior (PA) view was taken using a digital x-ray machine (Toshiba Medical Systems, KXO-50SS, Japan) with an x-ray tube voltage of 100-115 kVp and tube current of 6-8 mAs related to the Source to Image Distance (SID) of 180 cm. Image acquisition was achieved using the Konica Minolta CS7 software and Konica Minolta Aero DR unit (Konica Minolta Medical Imaging, USA). Measurements of clavicle radiogrammetry were performed at the midshaft of both clavicle bones, as described in the works by Kumar

and Anburajan.⁹ All measurements were made by using the image analysis tools of the DICOM viewer (INFINITT PACS 7.0, INFINITT Healthcare Co., Ltd.). Repeated measurements were made by one researcher. These measures were performed twice and then calculated the average of those values. The bone mass imaginary chest x-ray radiogrammetry acquisition were calculated as follow:

$$(a) \text{ The average periosteal width of clavicle} = (\text{clavicle periosteal width}_{\text{Right}} + \text{Clavicle periosteal width}_{\text{Left}}) / 2$$

$$(b) \text{ The average endosteal width of clavicle} = (\text{clavicle endosteal width}_{\text{Right}} + \text{Clavicle endosteal width}_{\text{Left}}) / 2$$

$$(c) \text{ The combined cortical thickness of clavicle} = (\text{The average periosteal width} - \text{The average endosteal width})$$

$$(d) \text{ The percentage of combined cortical thickness of clavicle (\%)} = (\text{The combined cortical thickness of clavicle} / \text{The average periosteal width of clavicle}) \times 100$$

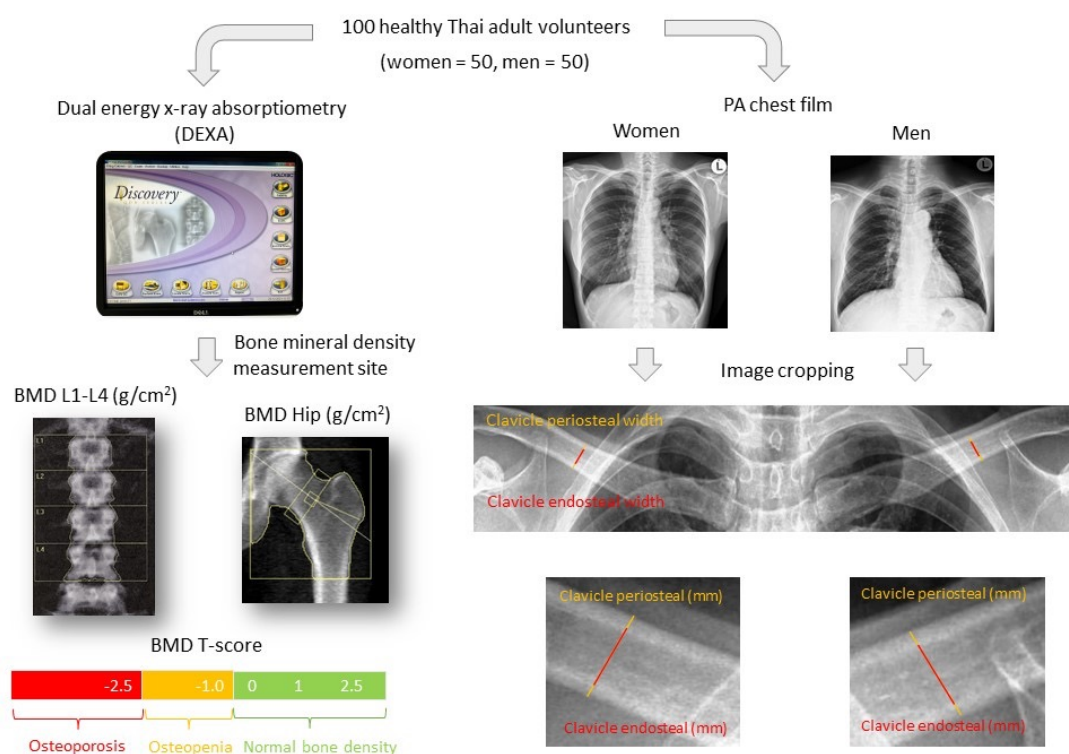


Figure 1. The experimental procedure.

Statistical analysis was performed using Microsoft Excel and the SPSS version 17.0 (SPSS Inc., Chicago, USA). Results were described as the mean and standard deviation (SD). An independent t-test was performed between normal and low bone mass group for each gender at the two areas in the lumbar vertebrae L1-L4 region and the one hip. Using confidence levels of 95%, a p-value less than 0.05 was considered as statistically significant. Afterwards, the Pearson's correlation analysis was used to measure the strength and direction of the linear relationship between the bone mass measurements performed by the DEXA and the clavicle radiogrammetry measured from the chest radiograph.

Results

A total of 100 healthy Thai adult volunteers received a DEXA bone density scan and a chest x-ray examination. Table 1 shows a summary of results which included relevant descriptive statistics whereby the data were expressed as

mean $\pm$ standard deviation (SD) by gender and the BMD level at the lumbar vertebrae L1-L4 and the hip position. The population consisted of 50 women with a mean age of 58 ± 11.98 years (range 32-75 years), and 50 were men with a mean age of 58 ± 12.42 years (range 24-75 years). Using diagnostic criteria regarding the severity of osteoporosis developed published by WHO, the normal BMD, T-score ≥ -1.0 , from 18 women and 28 men was established as standard values; Equally important, a low bone mass, T-score ≤ -1 (combination of osteopenia and osteoporosis), from 32 women and 22 men was recorded.

Data in Table 1 presents descriptive statistics of the selected participants. Men tended to have slightly higher values than women. The mean value of the weight, height, and BMI revealed diminished amounts when comparing both women and men who were found to have low bone mass values and the normal bone mass values. There was no statistically significant difference in weight, height, and BMI between the normal and the low bone mass in both

men and women ($p>0.05$). Measurements of the BMD using the DEXA at the lumbar area of vertebrae, the L1-L4 segments, and the hip position was significantly lower in low bone mass group when compared to the normal group ($p<0.05$) for both women and men. In addition, the mean value of clavicle cortex measurements, the clavicle endosteal width; the combined cortical thickness of clavicle; and the percentage of

combined cortical thickness of clavicle in normal women, revealed diminished amounts when comparing between normal and low bone mass group, and it was statistically significant ($p<0.05$). Regarding the measured clavicle periosteal width, there was no significant difference between groups in both genders ($p=0.37$ in women, and $p=0.10$ in men).

Table 1 Demographic information, clinical characteristics, bone mineral density, and clavicle radiogrammetry relating to participants.

Variables	Total women = 50 Min-Max age (years) = 32-75				Total men = 50 Min-Max age (years) = 24-76			
	Low bone mass (n=32)			t- test (p value)	Low bone mass (n=22)			t- test (p value)
	Normal (n=18)	Osteopenia (n=21)	Osteoporosis (n=11)		Normal (n=28)	Osteopenia (n=22)	Osteoporosis (n=0)	
Weight (kg)	56.7±8.30	52.4±7.99		0.08	72.2±7.38	65.4±9.87		0.20
Height (cm)	155.1±4.87	154.5±5.42		0.69	169.2±6.60	166.4±5.48		0.11
BMI (kg/m ²)	23.6±3.74	21.9±2.99		0.08	25.3±2.78	23.6±3.51		0.07
Bone mineral density (BMD) (g/cm ²)								
BMD L1-L4	1.045±0.09	0.094±0.10		0.00*	1.097±0.11	0.875±0.09		0.00*
BMD hip	0.816±0.09	0.603±0.09		0.00*	0.861±0.14	0.674±0.06		0.00*
Clavicle radiogram on the chest x-ray film at midpoint of clavicle								
1. Clavicle periosteal width (mm)	10.47±1.78	10.18±1.05		0.37	13.46±1.20	12.86±1.32		0.10
2. Clavicle endosteal width (mm)	4.01±0.61	4.86±0.68		0.00*	5.03±0.78	5.79±0.56		0.00*
3. Combined cortical thickness (mm)	6.46±.86	5.31±0.66		0.00*	8.43±1.11	7.07±0.97		0.00*
4. Percent of combined cortical thickness (%)	61.73±3.98	52.23±4.19		0.00*	62.56±5.33	54.85±3.15		0.00*

Note: Values are presented as mean±SD, n:number of participants, (*) indicates the $p<0.05$ that there is statistically significant.

The scatter plots represent the clavicle thickness measurements from clavicle radiograms that were related to the BMD in women with normal bone mass density and women with low bone mass as shown in Figure 2 and 3. Regarding the BMD in the lower lumbar spine area (L1-L4), the results showed a moderate-to-strong correlation between the BMD levels and the clavicle radiograms on chest x-ray film ($r=-0.61$ to 0.77). The measurements of the clavicle periosteal width; the clavicle endosteal width; the combined cortical thickness of clavicle, (the outer minus the inner clavicle cortex); and the percentage of the combined cortical thickness of the clavicle which had positively correlated to the BMD lumbar region. Only the clavicle endosteal width showed a negative correlation to the BMD on the L1-L4 segments. Results of the hip evaluation found that the value of r varied from -0.01 to 0.75 , which indicated that there was a weak-to-strong correlation. The clavicle periosteal and clavicle endosteal width showed a negative correlation with the BMD of the hip position, while the combined cortical thickness of the clavicle and the percentage of combined cortical thickness of the clavicle showed a positive correlation with the BMD of the hip position.

Regarding the patterns and trends concerning men, the clavicle thickness measurements were like that found in women. Scatter plots of clavicle thickness measurements against BMD between two groups are shown in Figure 4 and 5. In the lumbar spine, the results showed a weak-to-moderate correlation between the BMD levels and the clavicle radiograms on the chest x-ray films ($r=-0.22$ to 0.58). The mean value of clavicle cortex measurements, the clavicle periosteal width; the combined cortical thickness of clavicle, and the percentage of combined cortical thickness of clavicle had positively correlated with the BMD of the L1-L4 region. Only the clavicle endosteal width showed a negative correlation with the BMD of the lumbar region. In the hip position, it was found that the value of r varied from 0.30 to 0.52 , which indicated that there was a weak-to-moderate correlation. The measurement of the clavicular cortical thickness such as clavicle periosteal width; combined cortical thickness of clavicle; and the percentage of combined cortical thickness of clavicle showed a positive correlation to the BMD of the hip position, while the clavicle endosteal width showed a negative correlation to the BMD hip region.

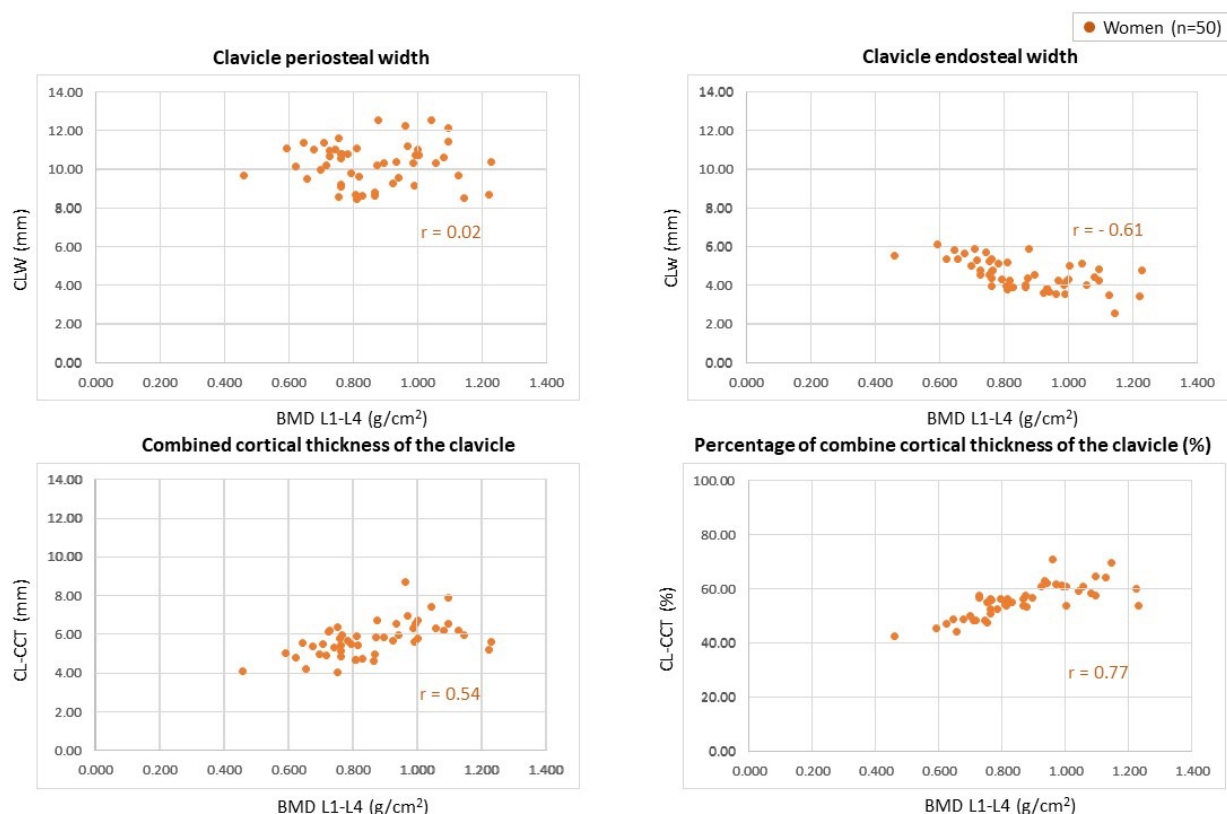


Figure 2. Scatter plots which represent the clavicle thickness measurements from clavicle radiograms that were related to bone mineral density of the lumbar spine region (L1-L4) in women with normal bone mass and women with low bone mass. Strength of a linear relationship denotes the correlation r value.

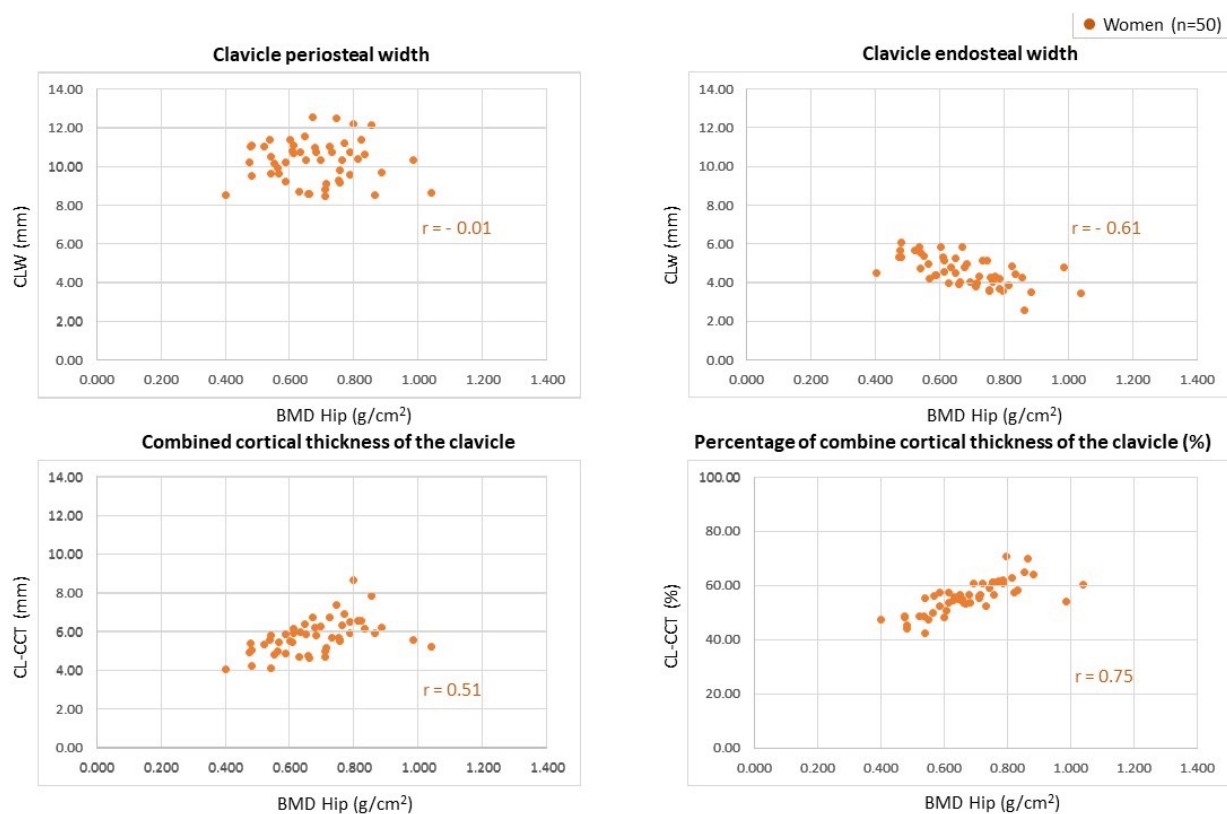


Figure 3. Scatter plots that represent the clavicle thickness measurements from clavicle radiograms that were related to the bone mineral density of the hip position in women with normal bone mass and women with low bone mass. Strength of a linear relationship designates the correlation r value.

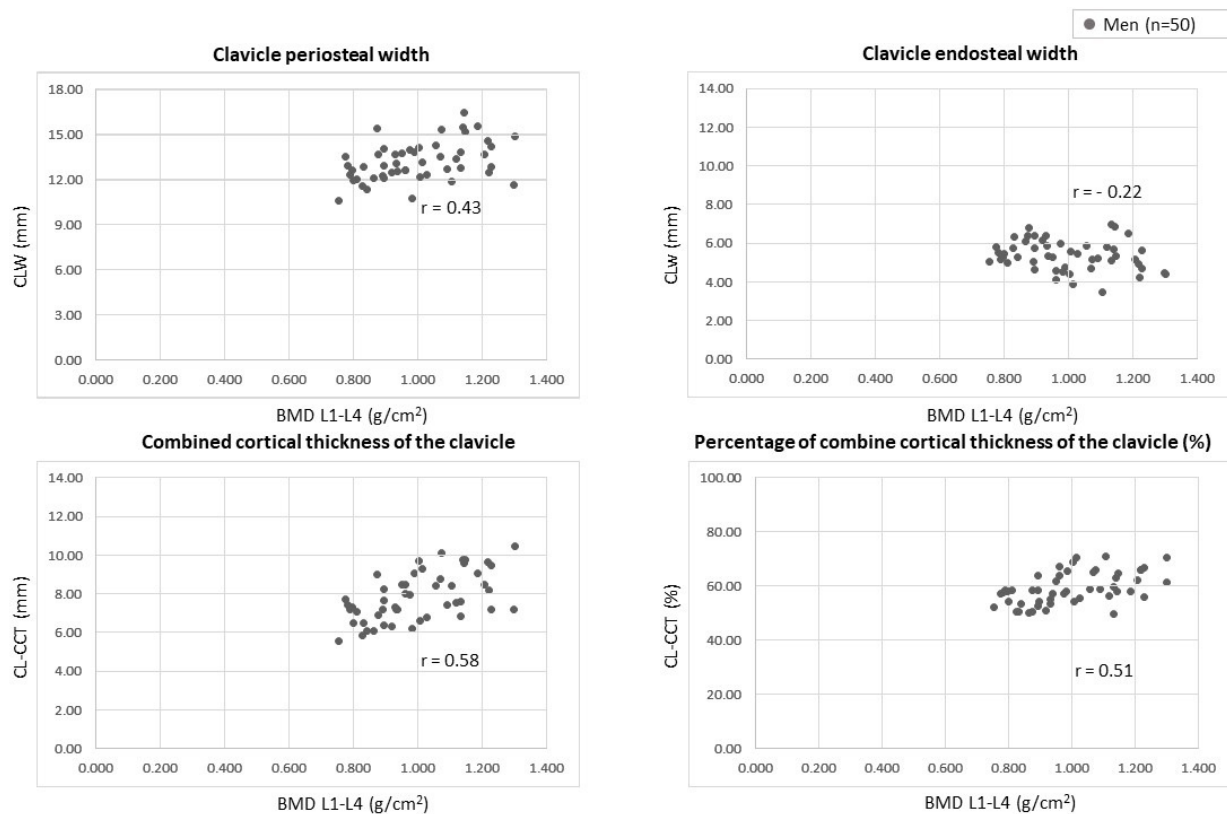


Figure 4. Scatter plots which represent the clavicle thickness measurements from clavicle radiograms that were related to the bone mineral density of the lumbar spine region (L1-L4) in men with normal bone mass and men with low bone mass. Strength of a linear relationship indicates the correlation r value.

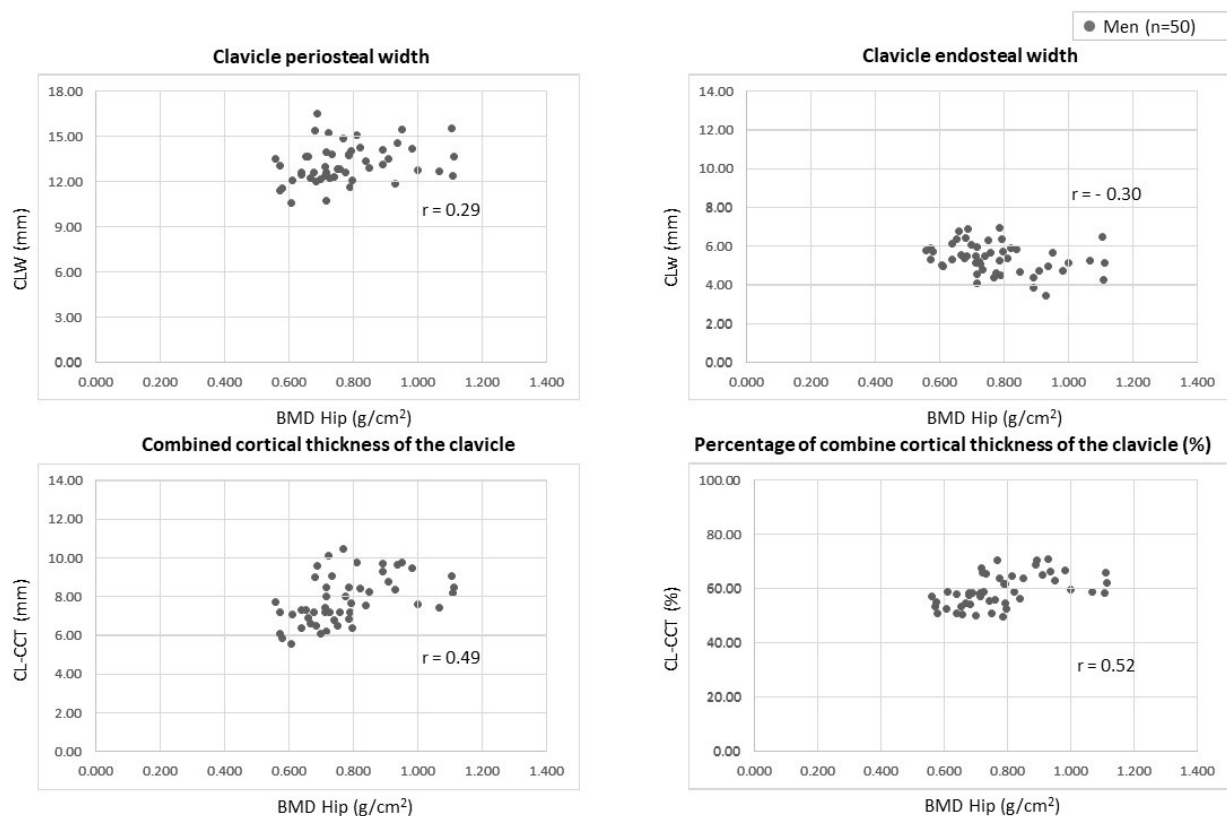


Figure 5. Scatter plots which represent the clavicle thickness measurements from clavicle radiograms that were related to the bone mineral density of the hip position in men with normal bone mass and men with low bone mass. The strength of a linear relationship also denotes by the correlation r value.

Discussion

Based on bone mineral density T-score, the findings indicated that the prevalence of osteopenia is higher than that of osteoporosis among participants who living in Phitsanulok Province. Regarding both women and men, as the age of individual increases, there is a reduction in the bone mass as shown in Figure 6. Elderly is associated with

a decrease that effects bone mineral density T-score at both the lumbar spine and the hip position. This was particularly relevant to the BMD values at the hip joint, which were lower than the BMD at the lumbar spine. The pattern observed in our study was consistent with previous findings.¹²⁻¹⁴

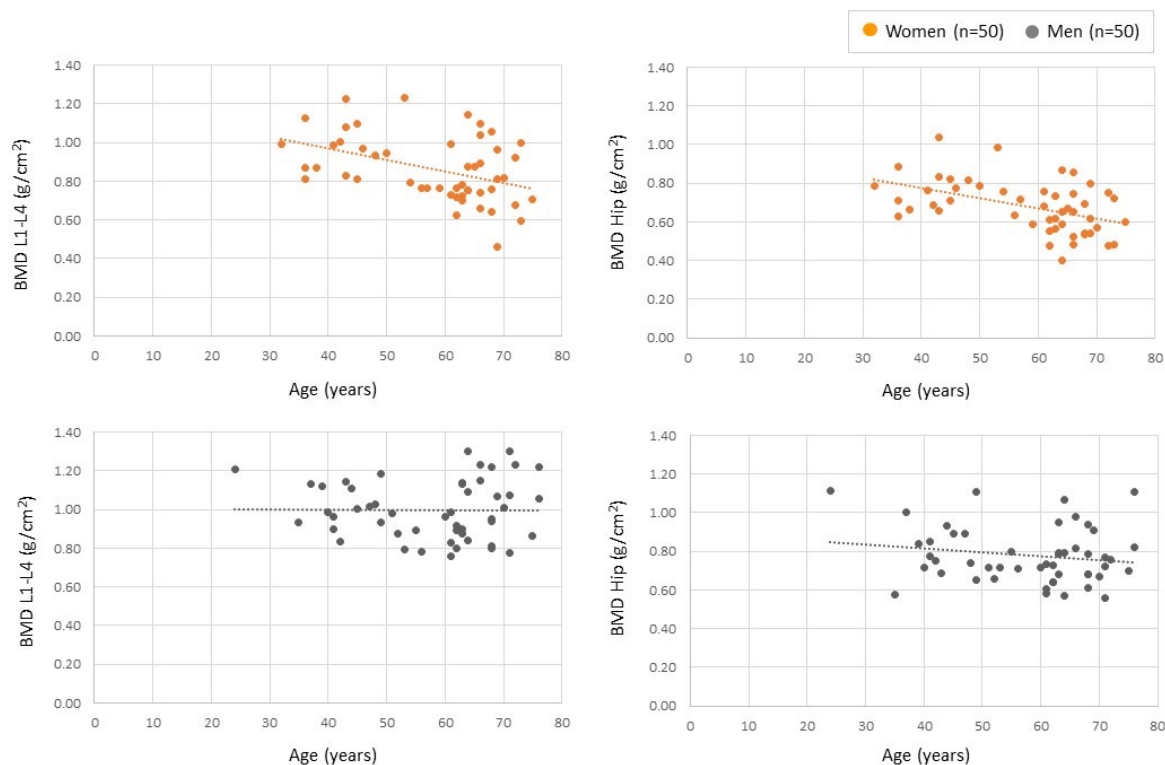


Figure 5. Relationship between age and two separate BMD sites at the lumbar vertebrae L1-L4 segments (left), and the hip position (right) of the women participants (orange dots) and men participants (black dots).

The demographic distribution of participant was dissimilar. The variable different according to gender, age, weight, height, BMI, and other factors associated. The lower bone mass observed in the women population than men. An explanation for these findings included menopause status that women with early menopause are having lower BMD than those with normal and late menopause.¹⁵ However, alternative explanations regarding to the reduction of the BMD and may the influence the outcomes of weight loss, which is linked to bone loss in middle aged women.¹⁶ Concerns regarding factors that influence bone density were broadly discussed.¹⁷⁻¹⁹ However, this finding suggests that additional investigation in the demographical and clinical variables influencing BMD levels are considered.

A thinning of clavicle cortical thickness was found in the low bone mass for both genders. The measured of the clavicle periosteal width; the combined cortical thickness of clavicle; and the percentage of combined cortical thickness of clavicle showed a positive correlation concerning the BMD T-score by DEXA. Only the clavicle endosteal width showed a negative correlation with BMD. The result of clavicular cortical thickness measurements showed

a decline of clavicle cortex with age in both women and men, however particularly higher in elderly individuals. A greater thinning of cortical thickness of clavicle was found in individuals with poor bone quality. Women were reported to exhibit a higher rate of bone loss than men. It was found that cortical thickness of clavicle in low bone mass women decreased by 17.8% (5.31 mm/6.46 mm) compared to normal women, while in men, there was lesser decline 16.13% (7.07 mm/8.43 mm) between groups, respectively. The average of clavicle endosteal width in normal women and low bone mass were around 4.01 mm and 4.86 mm, while in men were 5.03 mm and 5.79 mm, respectively. The average of clavicular cortical thickness obtained from experiments were observed within the range of threshold values done in south Indian woman (around 4.20 mm).⁹

The advantage of radiogrammetric method, which has been taken of the chest radiograph, can extracted essential data, which provide the medical staff with information pertaining to the clavicle cortex that influences factors such as size, thickness, texture, or shape feature in the assessment of osteoporosis. There have been few studies performed that used a combination of radiogrammetric

method with other imaging modalities. A study conducted by Maciel *et al.* found that texture attributes extracted from routine T2 sagittal Fast Spin Echo (FSE) imaging of the lumbar spine showed a positive correlated with the BMD.²⁰ They supported the use of quantitative analysis relating to the image texture required to predict an osteoporotic fragility fracture. However, the measurement of clavicular cortical thickness may be influenced by subject contrast and digital image quality. In future investigations, it might be possible using the plot profile instead of the straight-line measuring tool to minimize an error in the measurement.

This study has some limitations. Firstly, using opportunity sampling to recruit participants found sample sizes were unequal when relating the normal bone mass and low bone mass. There were women with osteoporosis (n=11); conversely, there no cases found for men (n=0). As a result of the low numbers of adults participating in this study, it is necessary to exclude adults aged over 75 years old in future studies. Secondly, the sensitivity, specificity, and accuracy for this study demands lengthier observation of this process. However, this study provides preliminary data to encourage the usefulness of clavicle radiograms made from a PA chest film and demonstrates the relationship between measured BMD by DEXA and clavicle radiograms variables among Thai adults.

Conclusion

The use of clavicle radiograms to measure the clavicle cortex thickness on the chest x-ray images showed a gradual thinning of the cortex with aging. By comparison, the measurements of clavicle cortex thickness showed a moderate relationship with BMD T-score from DEXA in the assessment of osteoporosis.

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Conflicts of interest

The author declares no conflicts of interest in this research.

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