Proximal Femoral Bone Geometry in Osteoporotic Hip Fractures in Thailand

Tanawat Vaseenon MD*, Sirichai Luevitoonvechkij MD*,
Sirianong Namwongphrom MD, PhD**, Sattaya Rojanasthien MD*

** Department of Orthopaedics, Faculty of Medicine,Chiang Mai University, Chiang Mai, Thailand*
*** Nuclear Medicine Unit, Department of Radiology, Faculty of Medicine, Chiang Mai University, Chiang Mai, Thailand*

Background: *A number of different bone geometries have been reported to be correlated with osteoporosis, bone mineral density and fractures. Those correlations are used for diagnosis, treatment and prediction of fracture risk in osteoporosis cases. However, there have been no studies of significant bone parameters predicting osteoporosis and hip fracture in Thailand.*

Objective: *To evaluate the correlation between geometric parameters of the proximal femur and both the Singh index and bone mineral density as well as to investigate the relationship between those two metrics and osteoporotic hip fracture in the Thai population.*

Material and Method: *Forty-four Thai patients with osteoporotic hip fractures and forty-five healthy Thai people matched for age and gender were included in the present study. Bone mineral density and bone geometry from plain hip radiographs of non-fracture sites in the fracture group and proximal femur radiographs of the same site in the healthy group were measured. That data were analyzed to determine levels of correlation. Bone geometries were also analyzed to determine hip fracture predictive capacity.*

Results: *Correlation between the Singh index and bone mineral density was significant ($p<0.01$), with a moderate degree of agreement. The radiograph measurement of the width of the femoral medial neck cortex was the only parameter which was statistically significantly correlated with both osteoporosis and with osteoporotic hip fracture ($p = 0.014$ and $p = 0.035$, respectively). Each 1 mm reduction in the width of the femoral medial neck cortex increased the osteoporotic hip fracture risk by a factor of 2.7 (OR = 0.37, 95% CI = 0.15-0.93).*

Conclusion: *In the Thai population, bone geometry from plain radiographs can help predict the risk of osteoporotic hip fracture. Osteoporosis is correlated with a low Singh index value. The width of the femoral medial neck cortex is a reliable predictor of hip fracture risk.*

Keywords: *Bone geometry, Osteoporosis, Hip fracture, Singh index, Hip axis length, Medial femoral neck width*

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Osteoporosis is a disease of the bone characterized by low bone mass leading to an increased risk of fracture. Hip fractures are common among patients with osteoporosis, and osteoporotic hip fractures increase the mortality rate in older people(1,2). As the number of elderly people in the world increases, osteoporosis and hip fractures are expected to be a growing public health problem(3). In 1990, the number of hip fractures reported worldwide was 1.66 million. That number is expected to rise to 6.26 million by 2050(1). In Thailand, the crude incidence of hip fracture has increased by an average of 2.02% per year over the period 1997 to 2013(4). One-year and ten-year mortality rates after hip fractures in Thailand in 2010 were 18% and 68%, respectively(5).

Currently, dual energy X-ray absorptiometry (DXA) is used to assess bone mineral density (BMD) and to assess the risk of osteoporotic fractures in the elderly. Low bone mineral density at the femoral neck has been shown to be a reliable predictor of osteoporotic hip fracture risk(6,7). Several studies have proposed using the Singh index to measure the density of the proximal femur trabecular bone to evaluate the degree of osteoporosis(8-14). Previous studies have reported a good correlation between the Singh index and BMD. Hip geometry parameters measured using conventional plain radiographs can also be used to predict hip fracture risk(15-17).

Hip geometry parameters measured from a plain radiograph such as cortical thickness index and canal-to-calcar ratio are correlated with osteoporosis(18).

Correspondence to:
Vaseenon T, Department of Orthopaedics, Faculty of Medicine, Chiang Mai University, Chiang Mai 50200, Thailand.
Phone: 053-945544, Fax: 053-946442
E-mail: tvaseenon@yahoo.com

Other studies have indicated that parameters such as femoral head-neck diameter, femoral neck cortex width, medial calcar femoral cortex width and femoral shaft cortex width, are directly related to low BMD[19,20].

The objectives of the present study were to evaluate the correlation between bone geometry parameters of the proximal femur, including the Singh index and bone mineral density, and osteoporotic hip fractures in the Thai population.

Material and Method

Forty-five Thai patients with osteoporotic hip fractures were recruited at the Orthopaedic Clinic, Chiang Mai University Hospital, between January and June 2010. Another forty-five healthy Thai people matched for age, gender and underlying diseases were recruited as a control group. Exclusion criteria were a pathologic fracture; previous hip fracture; severe medical conditions causing falls such as hemiplegia, brain lesion, cerebral palsy, and poliomyelitis; and a history of secondary osteoporosis. Plain radiographs of both hips in AP view were taken of both groups. Subjects were in supine position with 25 degrees of hip internal rotation. All subjects underwent dual-energy X-ray absorptiometry of both hips using the Discovery a (S/N 82938) scanner at Chiang Mai University Hospital.

Hip bone geometry parameters from the plain radiographs of the fracture group were measured on the non-fractured side and on the corresponding side in the control group. Two investigators (Vaseenon T and Luevitoonvechkij S) measured each of the radiographs twice (a total of four sets of measurements), then the average for each parameter was calculated. Details of the measurements taken are as follows: (1) Hip axis length (HAL) - length along the femoral neck axis from below the lateral aspect of the greater trochanter through the femoral neck to the inner pelvic brim; (2) Femoral neck shaft angle (FNA) - the angle formed between the femoral neck and the shaft of the femur; (3) Femoral head width (FHW) - width at the femoral head region; (4) Femoral neck width (FNW) - width at the narrowest part of the femoral neck region of interest; (5) Femoral medial neck cortex (FMNC) - femoral neck cortical thickness at the level of the width measurement of medial cortex of the femoral neck; and (6) Trochanteric width (TW) - width at the trochanteric region from the upper border of the lesser trochanter to the vastus ridge of the greater trochanter[15]. The Singh index was also graded for both groups[8].

Statistical analysis

Inter- and intra-observer agreement was analyzed by kappa correlation tests. For correlations between the Singh index and femoral BMD, Spearman correlation coefficients were analyzed. Logistic regression was performed to analyze the power of the geometry of the proximal femur in predicting hip fracture risk. STATA software (version 10.0) was used for all statistical analyses.

Results

The intra-class correlation coefficient showed an excellent measurement agreement for both inter-observer reliability (r = 0.85) and intra-observer reliability (r = 0.89). The mean T-score of the femoral neck BMD in the hip fracture group (-2.9±1.0) was significantly lower than that for the control group (-2.3±0.9), $p = 0.005$ (Table 1).

The median Singh index values of the hip fracture and the control groups were 3 and 4, respectively. Defining a Singh index of grade 3 or less to be severe osteoporosis, the percentage of subjects with severe osteoporosis among the fracture and the control groups were 61.4 and 28.9%, respectively. This inter-group difference was statistically significant ($p = 0.003$). The correlation between the Singh index and T-scores of femoral neck BMD was also significant (r = 0.51, $p<0.0001$). Regression analysis showed the Singh index to be a good predictor of femoral neck BMD ($p<0.001$).

Regarding bone geometry and T-scores, radiographic parameters of FMNC and TW were statistically significant for T-scores less than -2.5 with *p*-value of 0.014 and 0.020, respectively. Comparison of the hip fracture and control groups showed that FMNC and FNW were statistically significant predictors of risk for osteoporotic hip fracture with *p*-value of 0.035 and 0.042, respectively (Table 2).

Logistic regression showed that the each 1 mm reduction in FMNC increased the osteoporotic hip fracture risk by a factor of 2.7 (OR = 0.37, 95% CI

Table 1. Hip geometric characteristics in the hip fracture and non-fracture (control) groups

	Fracture	Non-fracture	*p*-value
Number	44	45	
Mean age (years)	77.6	71.7	0.210
Bone mineral density	-2.9±0.9	-2.3±1.0	0.005
Singh index (stage)	3.0±1.0	3.8±0.9	0.003

= 0.15-0.93). Each millimeter increase in FMNC reduced the osteoporotic hip fracture risk by a factor of 1.44 (OR = 1.44, 95% CI = 1.01-2.07) (Table 3).

Discussion

The present study evaluated the correlation of bone geometry measurements including the Singh index, in the Thai population between a group with osteoporotic hip fractures and a non-fracture control group. The osteoporotic hip fracture group presented with low Singh index levels and changes in bone geometry parameters that indicated a reduction in the width of the FMNC.

Osteoporotic hip fracture is a serious and growing health problem in Thailand. The rising incidence of osteoporotic hip fractures in Chiang Mai, Thailand, was reported in 2007 to be increasing by an average of 2% per year[4]. Bone mineral density (BMD) at the femoral neck area recognized standard for assessing osteoporosis. Furthermore, low bone mineral density is a good predictor of risk of hip fracture[20], and fracture rates increase with the degree of osteoporosis[6]. The present study revealed that most members of the hip fracture group had a BMD lower than -2.5 and that intertrochanteric fracture in that group were more common than femoral neck fractures. These finding supports previous studies that reported a higher incidence of osteoporotic hip fractures among the intertrochanteric fractures than femoral neck fractures in the general population.

The Singh index, which is based on the trabecular pattern of the proximal femur, is another method of assessing osteoporosis[8]. Previous studies have indicated that the Singh index provides a reliable assessment of osteoporosis[21,22]. However, other studies have reported that the Singh index was not correlated with T-scores of femoral neck BMD[23]. In the present study, Singh index grades 1 to 3 were found to be significantly correlated with femoral neck BMD T-scores of less than -2.5. This indicates that the Singh index is suitable for assessing osteoporosis in hospitals in Thailand and potentially elsewhere where DXA scans are not available.

Some studies which investigated bone geometries using hip radiographs found that bone strength of the proximal femur is related to bone geometry[21,22]. Measurements of HAL and FNA were described as the most reliable predictors of osteoporotic hip fracture risk[17]. In the present study, however, FMNC was found to be the only significant parameter for predicting osteoporosis and osteoporotic hip fracture. Thai Nurses and physicians have found FMNC to be very helpful in predicting osteoporosis: a reduction in FMNC measured during an annual follow-up was seen as an indication of an increased risk of osteoporotic hip fracture. Future studies need to focus on the FMNC parameters as potential factors

Table 2. Regression of bone mineral density of the femoral neck with age and hip geometries

Variables	*p*-value
Age (years)	0.031*
Femoral medial neck cortex (FMNC)	0.014*
Hip axis length (HAL)	0.145
Femoral neck shaft angle (FNA)	0.423
Femoral head width (FHW)	0.836
Femoral neck width (FNW)	0.724
Trochanteric width (TW)	0.020*

* Statistically significant predictors of bone mineral density of the femoral neck

Table 3. Parameters of proximal femur

Variables	Odds ratio	Odds ratio (95% CI)	*p*-value
Bone mineral density	0.78	0.33-1.87	0.577
Age	0.97	0.89-1.06	0.54
Singh index	0.74	0.34-1.64	0.46
Femoral medial neck cortex (FMNC)	0.37	0.15-0.93	0.035*
Hip axis length (HAL)	0.97	0.86-1.11	0.70
Femoral neck shaft angle (FNA)	1.02	0.93-1.13	0.64
Femoral head width (FHW)	0.95	0.65-1.41	0.81
Femoral neck width (FNW)	1.44	1.01-2.07	0.042*
Trochanteric width (TW)	0.91	0.73-1.17	0.49

* Statistically significant predictors for hip fracture

in predicting osteoporosis and related fractures in other populations.

Conclusion

Bone geometry from plain radiographs can help predict the risk of osteoporotic hip fractures. Osteoporosis is correlated with a low Singh index. The parameter of FMNC is the only reliable predictor of hip fracture in the Thai population.

Limitations

There were two limitations in the present study. First, there were a limited number of cases. Including additional subjects in a future study would reduce the margin of error. Second, all measurements of bone parameters from radiographs used picture archiving communication system software. If other software should be used, recalibration of the software program would be necessary.

What is already known on this topic?

There were some studies mentioned about bone geometry in comparing with osteoporotic and nonosteoporotic diagnosis and resulted in some bony parameters from DXA scan and plain radiographs. There also were some studies comparison between osteoporotic fracture and nonosteoporotic fracture regarding to changing of bone geometry. However, there were no studies about bone geometry in two group of patients and studying into each patient factors related in Thailand.

What this study adds?

Adding the knowledge of femoral neck cortical thickness is a very helpful bone parameter to detect osteoporosis. It is also a risk factor of osteoporotic hip fracture that need to be aggressive prevention in that kind of patients.

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Potential conflicts of interest

None.

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โครงสร้างกระดูกโคนขาในผู้ป่วยกระดูกสะโพกหักจากโรคกระดูกพรุนในประเทศไทย

ธนวัฒน์ วะสีนนท์, ศิริชัย ลือวิฑูรเวชกิจ, ศิริอนงค์ นามวงศ์พรหม, สัตยา โรจนเสถียร

ภูมิหลัง: *ค่าโครงสร้างของกระดูกโคนขามีความสัมพันธ์กับโรคกระดูกพรุน กระดูกหัก และความหนาแน่นกระดูก ค่าต่าง ๆ นำมาใช้วินิจฉัยรักษาและทำนายการเกิดโรค อย่างไรก็ตามยังไม่มีค่าใดที่ใช้ทำนายได้ทั้งการวินิจฉัยโรคกระดูกพรุนและภาวะกระดูกหักในประเทศไทยมาก่อน*

วัตถุประสงค์: *หาความสัมพันธ์ของค่าโครงสร้างกระดูกโคนขารวมถึงค่าซิงค์อินเด็กส์กับความหนาแน่นกระดูกและโรคกระดูกสะโพกหัก*

วัสดุและวิธีการ: *ผู้ป่วยสี่สิบห้าคนที่มีกระดูกสะโพกหักและคนที่ไม่มีกระดูกสะโพกหักที่มีอายุและเพศเดียวกันได้รับการตรวจความหนาแน่นกระดูก ถ่ายภาพทางรังสีของกระดูกสะโพกโดยวัดค่าจากข้างที่ไม่หัก วัดค่าโครงสร้างกระดูกโคนขาและหาความสัมพันธ์ของค่าโครงสร้างกระดูกโคนขากับความหนาแน่นกระดูก รวมทั้งหาค่าโครงสร้างกระดูกที่เป็นตัวพยากรณ์การหักของกระดูกสะโพก*

ผลการศึกษา: *พบว่ามีความสัมพันธ์ปานกลางของค่าโครงสร้างค่าซิงค์อินเด็กส์กับความหนาแน่นกระดูกอย่างมีนัยสำคัญทางสถิติ ค่า femoral medial neck cortex เป็นค่าโครงสร้างที่สัมพันธ์กับโรคกระดูกพรุนและกระดูกหักจากโรคกระดูกพรุน พบว่ามีความสัมพันธ์ปานกลางของค่าโครงสร้างค่าซิงค์อินเด็กส์กับความหนาแน่นกระดูกอย่างมีนัยสำคัญทางสถิติ โดยค่าที่ลดลง 1 มิลลิเมตร จะเพิ่มความเสี่ยงในการเกิดโรคกระดูกหักจากโรคกระดูกพรุนถึง 2.7 เท่า*

สรุป: *ค่าโครงสร้างกระดูกที่วัดจากภาพถ่ายทางรังสีสามารถทำนายการเกิดโรคกระดูกหักจากภาวะกระดูกพรุนได้ โดยค่าซิงค์อินเด็กส์สัมพันธ์กับค่าความหนาแน่นกระดูก และค่า femoral medial neck cortex สัมพันธ์กับภาวะกระดูกหักจากโรคกระดูกพรุน*
