SONOGRAPHIC PARAMETERS OF QUADRICEPS MUSCLE AND BONE MINERAL DENSITY OF THE HIP: A STUDY IN NORMAL THAI ADOLESCENTS

Suphaneewan JAOVISIDHA MD.[1] Suthiwan KWANBUNBUMPEN Ph.D.[2]
Rojana SIRISRIRO MD.[1] Parichard ROJANAPLAKORN M.Sc. (Bios)[3]
Puangthong KRAIPIBOON MD.[1]

ABSTRACT

Purpose. To study the correlation between sonographically measured parameters of quadriceps muscle and bone mineral density (BMD) of proximal femur in normal Thai adolescents. **Material and Methods.** Fifty-seven school children and normal adolescents were included in this study (30 males, aged 10-17 years old [mean age = 13.2 years old]; and 27 females, aged 9-18 years old [mean age = 13.1 years old]). All subjects were undergone sonographic measurement of thickness, circumference, and cross-sectional area (CSA) of quadriceps muscle as well as thickness of subcutaneous fat of non-dominant thigh. Ipsilateral proximal femoral BMD was measured using Dual-energy X-ray absorptiometry (DEXA). Spearman Rank Correlation and Pearson Product Moment Correlation were used for statistical analysis. **Results and Conclusion.** In females, all quadriceps parameters showed statistically significant correlation ($p<.001 - p<.05$; muscle circumference showed the best correlation) with proximal femoral BMD at all ROIs. In male subjects, the quadriceps parameters showed significant correlation ($p<.01 - p<.05$) with BMD of the femoral neck & the trochanter. No significant correlation was found between quadriceps parameters and BMD of Ward's triangle and thickness of subcutaneous fat.

INTRODUCTION

Real-time sonography has been proved to be a useful imaging technique for the visualization of normal and pathological muscle tissue.[1] The main advantages of the technique are that it is painless, non-invasive, harmless, and can be easily repeated to study the course of disease.[2-5] The quadriceps femoris muscle was frequently chosen to be studied because it is easily accessible and identifiable and not adjacent to femur, which excludes echo reflection of the bone-tissue interface.[6] The thickness of quadriceps muscle measured by ultrasound (US) was reported to change relating to certain diseases i.e., muscular dystrophy[1,7] and multiple organs failure.[8] Significant relationship was found between quadriceps muscle thickness and body weight in adult.[9] Cross-sectional area (CSA) of quadriceps muscle has also been widely studied, particularly in relation to muscle strength.[10-15]

ROI = Region of Interest.

[1] Department of Radiology, Ramathibodi Hospital, Mahidol University, Rama 6 street, Bangkok 10400, Thailand
[2] Department of Graduate Studies, Mahidol University, BKK.
[3] Department of Nursing, Ramathibodi hospital, BKK.

The purposes of this study were to determine the correlation between sonographically measured parameters of quadriceps muscle (the thickness, circumference, and cross-sectional area [CSA]) and bone mineral density (BMD) of the proximal femur and thickness of subcutaneous fat in normal Thai adolescents.

MATERIAL AND METHODS

This study is a part of a larger study on the effect of physical activity on musculoskeletal growth in Thai adolescents. Fifty-eight untrained, normal subjects were included in this study (30 males and 28 females). The age range in male subjects was 10-17 years old (mean age = 13.2 years old); and in females was 9-18 years old (mean age = 13.1 years old). All subjects were undergone sonographic measurement of the thickness, circumference, and cross-sectional area (CSA) of quadriceps muscle as well as the thickness of subcutaneous fat (Figure 1). Because we did measurement only on the non-dominant (left) thigh, one female subject who had non-dominant right side was excluded from the study.

Sonographic measurement. The ultrasound imaging was obtained by gray-scale system of the real-time scanner (Aloka SSD 680, Aloka Co., Ltd., Tokyo, Japan), using a 3.5-MHz linear array transducer. The subjects were examined in supine position with knee extended and the muscle relaxed. The mid thigh was identified as the midway point between the tip of greater trochanter and distal femur center between midpoint of the lateral femoral condyle and the superior fibula head. The electronic light pen was used to measure the parameters. The muscle circumference was calculated using the program of the ultrasound machine, by multiplying the total length of the trace line (cm.) by the scale factor. The cross-sectional area (CSA) was calculated in the same manner, by multiplying the area of one pixel (0.04 mm^2) by the total number of pixels enclosed within the trace line.

Bone mineral measurement. Bone mass measurement was taken, using the dual energy X-ray absorptiometry (DEXA)(LUNAR - DPX model, LUNAR Co., Madison, WI). Bone mineral density (BMD – [gm/cm^2]) of the proximal femur which composed of three regions of interest (ROI): the femoral neck, Ward's triangle, and the greater trochanter were measured. The BMD of proximal femur was performed only on non-dominant (left) side of the remaining 57 subjects in this study, and were analyzed using semi-automatic software of the LUNAR Co. The areas of femoral neck, Ward's triangle, and greater trochanter are shown in Figure 2.

Statistical Analysis. Spearman Rank Correlation and Pearson Product Moment Correlation were performed to determine whether there were correlation between the sonographically measured parameters of quadriceps muscle and the thickness of subcutaneous fat as well as BMD of ipsilateral proximal femur. The statistically significant correlation was considered when the p value was less than 0.05

RESULTS

In female; the thickness, circumference, and CSA of quadriceps muscle showed statistically significant correlation with thickness of subcutaneous fat and BMD of proximal femur in all ROIs (Table 1-3). The circumference of quadriceps muscle showed the most significant correlation (Table 2).

In male subjects; the thickness, circumference, and CSA of quadriceps muscle showed significant correlation with BMD of the femoral neck and the trochanter but not with BMD of Ward's triangle and the thickness of subcutaneous fat (Table 1-3).

Table 1: CORRELATION BETWEEN THICKNESS OF QUADRICEPS MUSCLE AND BMD OF IPSILATERAL PROXIMAL FEMUR, WHEN STRATIFIED SUBJECTS BY GENDER (FEMALE/MALE)

Parameters	Correlation co-efficient	(P value)
	Female (n=27) Age 10-17 (mean 13.2)	**Male (n=30)** Age 9-18 (mean 13.1)
Of non-dominant (left) side		
Femoral neck BMD	0.5158 (<.01)	0.4101 (<.05)
Ward's triangle BMD	0.5021 (<.01)	0.2801 (0.13)
Trochanteric BMD	0.5494 (<.01)	0.4437 (<.05)
Subcu.fat thickness	0.6194 (<.01)	0.0375 (0.84)

Table 2: CORRELATION BETWEEN CIRCUMFERENCE OF QUADRICEPS MUSCLE AND BMD OF IPSILATERAL PROXIMAL FEMUR, WHEN STRATIFIED SUBJECTS BY GENDER (FEMALE/MALE)

Parameters	Correlation co-efficient	(P value)
	Female (n=27) Age 10-17 (mean 13.2)	**Male (n=30)** Age 9-18 (mean 13.1)
Of non-dominant (left) side		
Femoral neck BMD	0.7086 (<.001)	0.4526 (<.05)
Ward's triangle BMD	0.6411 (<.001)	0.2528 (0.18)
Trochanteric BMD	0.6732 (<.001)	0.4873 (<.01)
Subcu.fat thickness	0.4771 (<.05)	0.1417 (0.46)

BMD = Bone Mineral Density.

Table 3: CORRELATION BETWEEN CROSS-SECTIONAL AREA (CSA) OF QUADRICEPS MUSCLE AND BMD OF IPSILATERAL PROXIMAL FEMUR, WHEN STRATIFIED SUBJECTS BY GENDER (FEMALE/MALE)

Parameters	**Correlation co-efficient**	**(P value)**
	Female (n=27) Age 10-17 (mean 13.2)	**Male (n=30)** Age 9-18 (mean 13.1)
Of non-dominant (left) side		
Femoral neck BMD	0.6951 (<.001)	0.4646 (<.05)
Ward's triangle BMD	0.6460 (<.001)	0.2705 (0.15)
Trochanteric BMD	0.6679 (<.001)	0.4965 (<.01)
Subcu.fat thickness	0.4795 (<.05)	0.0438 (0.82)

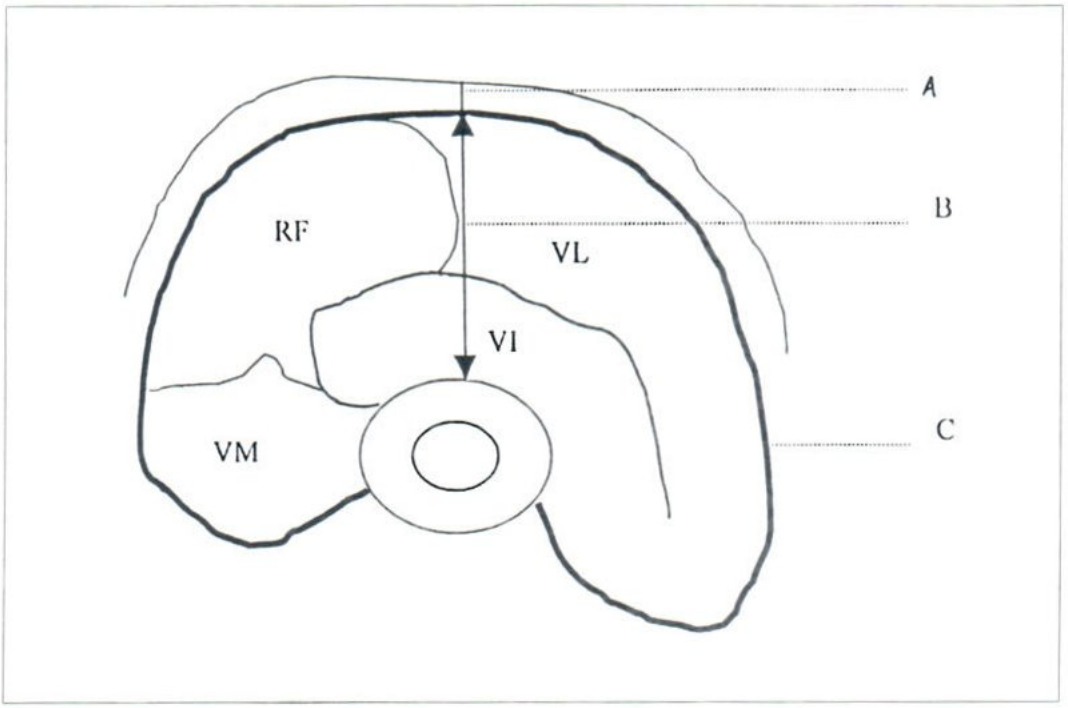

Fig. 1 Cross section of quadriceps femoris muscle, composing of four muscles; rectus femoris (RF), vastus lateralis (VL), vastus intermedius (VI), and vastus madialis (VM). The method of measurement of subcutaneous fat thickness (**A**), the muscle thickness (between arrowhead, **B**), and the circumference of muscle (thick black line, **C**) are demonstrated.

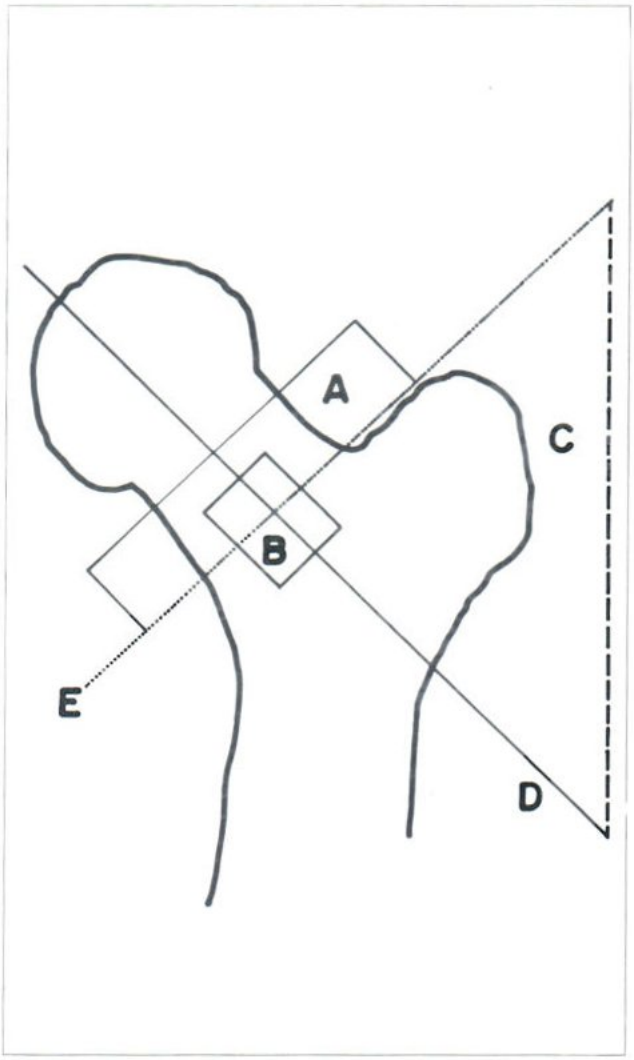

Fig. 2 Diagram of the areas of bone mineral density measurement in proximal femur. **A** (large rectangular) = femoral neck, **B** (small rectangular) = Ward's triangle, **C** (triangle) = trochanter, line **D** = axis, line **E** = the line drawn perpendicular to line **D**.

DISCUSSION

The quadriceps femoris muscle is the great extensor muscle of the leg. It can be divided into four parts; the rectus femoris, the vastus lateralis, the vastus medialis, and the vastus intermedius.[16] The tendons of the four divisions unite in the lower part of thigh to form a single strong tendon attaches to the base of patella. The quadriceps extends the leg upon the thigh. The rectus femoris assists in flexing the thigh on the pelvis, and also can extend the knee and flex the hip simultaneously.

Muscular forces influence bony configuration; in fact, normal skeletal development is dependent upon balanced muscle action.[17] The increase in BMD was reported to be dependent on height, weight, puberty, and other growth variables including skeletal muscle mass.[18] Heckmatt et al.,[19] in a study of 276 children from newborn babies to 12 years of age, noted that the thickness of quadriceps muscle also increased with age. The greatest increase was in the first two years of life, and there was no significant difference in the muscle thickness between sexes at any age. Most of the bone mass at multiple locations will be accumulated by late adolescence,[20] whereas the ability to produce strength proportional to the quadriceps muscle size is greater in young adult than in childhood.[10] These led us to study whether there were correlation between the parameters of quadriceps muscle, which is a strong muscle group supporting movement of lower extremity, and BMD of ipsilateral proximal femur as well as the thickness of subcutaneous fat.

In female subjects, we found statistically significant correlation between CSA of quadriceps muscle and BMD of proximal femur. During childhood, females had similar growth curves in muscle CSA to those of males. An apparent sex separation in muscle CSA took place at 13 years of age and after [21]. BMD was also reported to increase with age during childhood,[18] and bone mass accumulation in healthy female adolescents was pronounced over 3-year period (11-14 years of age).[22] These suggest the simultaneous time frame for bone mass accumulation and muscle growth, and may explain the significant correlation between quadriceps CSA and proxi-

mal femoral BMD in our study. The circumference and thickness of quadriceps muscle have seldom been studied relating to bone mass accumulation. We found significant correlation between the circumference ($p<.001$) and thickness ($p<.01$) of quadriceps muscle and BMD of proximal femur. Among the measured parameters, muscle circumference showed the best correlation with BMD of proximal femur at all ROIs ($r = 0.6411 - 0.7086$).

In male subjects, there was no significant correlation between the measured quadriceps parameters and the thickness of subcutaneous fat. Kanehisa et al.[21] found that in an age span from 13-15 years, fat CSA for males decreased while that for females increased. The decrease amount of fat in male adolescents at the time when muscle mass increased may be the cause of weak correlation in this present study. Bone mass accumulation in male increased significantly until the age of 17.5 years old.[18] The gain in BMD was high in a 4-year period (13-17 years of age), then the increment rate markedly declined. Lu et al.[18] noted that the increase in total-body BMD (TBMD) showed no difference between two sexes until after the age of peak TBMD in females, when the magnitude in the males became greater. The latter was related to higher lean tissue mass and weight. This suggested that TBMD, which is a function of cortical bone, was size dependent. The authors also found that the L2-4 BMD which represented trabecular bone was much less size dependent.[18] In our study, BMD of Ward's triangle which is the area composed almost entirely of trabecular bone also showed no significant correlation with quadriceps parameters, may be explained in a similar manner.

In conclusion, the thickness, circumference, and CSA of quadriceps muscle of non-dominant thigh shows significant correlation with ipsilateral proximal femoral BMD at all ROIs in female adolescents. In male subjects, those quadriceps parameters showed significant correlation only with BMD of the femoral neck and the trochanter, but not with BMD of Ward's triangle.

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