The Relevant Level to Estimate Girth Difference between Thighs after Anterior Cruciate Ligament Deficiency

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Background: *Manual thigh girth measurement is a simple tool to roughly estimate capacity change of the thigh. Yet, there is no good evidence supporting the most relevant anatomical landmarks to detect girth difference from the normal limb.*
Material and Method: *The present study consecutively enrolled 30 patients sustaining unilateral anterior cruciate ligament deficiency and measured both thigh girths in series at 2-cm intervals from anteromedial joint line until 30 cm cephalad. The measurements were also performed in intervals at 1/16 ratio of the thigh length marked between the tibial tuberosity (TT) and the anterior superior iliac spine (ASIS). The results from both normal and the injured side were compared by analyzing means and standard deviations for the statistical difference.*
Results: *Levels of significant mean girth difference between the two thighs were located at 18 cm and 20 cm above the anteromedial joint line or at 6/16 (3/8 or approximately 1/3) the thigh length measured from the TT towards the ASIS.*
Conclusion: *In patients with knee problems using deficient ACL as the prototype, the most relevant level to detect thigh girth difference from the normal side is located at 18 cm and 20 cm above the anteromedial knee joint line or at 6/16 (3/8 orapproximately 1/3) the thigh length measured from the TT towards the ASIS.*

Keywords: *Thigh, Circumference, Girth, Measurement, Anterior cruciate ligament*

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Atrophy of thigh muscles is common after knee injury or surgery[1]; for instance, anterior cruciate ligament (ACL) deficiency[2,3], meniscal injury[4] and total knee arthroplasty[5]. Volumetric capacity and cross-sectional area of thigh muscles can be assessed with different validities ranging from using magnetic resonance imaging (MRI)[6] to anthropometric estimate[7] and manual girth measurement. Precision among these methods in assessing muscle mass depends significantly on the ability to exclude other tissues (skin, fat, fascia, bone) in the measurement.

In orthopaedic practice, thigh muscle atrophy can be roughly reflected by magnitude of the thigh girth, which has also been advocated as a valid predictor for certain clinical conditions. Examples include positive association of small thigh circumference with incidence of cardiovascular and coronary heart disease[8] and maximum thigh circumference as an indicator of birth weight[9]. Detection of thigh girth changes may not require sophisticated methods while manual measurement is more clinically practical by using a measuring tape.

Thigh girth is commonly measured bilaterally to detect dimensional alteration after trauma, disease states or muscle training in one limb by comparing with the other normal limb. To the best of our knowledge, literatures have not provided enough evidence to unanimously delineate the most relevant landmarks for this measurement. Different palpable body structures are suggested as a starting point towards the level where the girth is measured, such as medial knee joint line[10] and upper pole of the patella[11]. In addition, thigh level for the measurement is also not consistently defined. The desired level to measure is often visually appraised by comparing with the related contralateral portion.

Reliable quantification of unilateral thigh girth change requires a valid guideline to detect the most precise level to indicate the maximal significant difference between limbs. The present study is intended to find out the solution using patients sustaining ACL deficiency as the model.

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Material and Method

Sample size was calculated for 0.8 probabilities to correctly reject the null hypothesis (power), given p-value at 0.05 with 0.5 centimeters acceptable error and population variance = 0.67 from our previous pilot study. Samples required would thus be 21.

Patients with at least 3 months history of unilateral ACL deficiency were chosen as the prototype and were consecutively enrolled in the presentstudy. The diagnosis was made by positive anterior drawer, Lachman and Slocum (or pivot shift) tests and by KT-1000™ arthrometer (MEDmetric®, San Diego, California) assessment. The diagnosis would later be confirmed by arthroscopic findings. Other inclusion criteria were age limit between 15 and 45 years old and individuals who consented to undergo comprehensive measurements. Excluded conditions comprised non-conforming age group, any trauma or diseases affecting one or both lower limb functions, conditions less than 3 months after the initial injury, swelling or deformities affecting the anatomical landmarks, those who had been formally trained to practice thigh muscle exercises and arthroscopic findings not convincing ACL deficiency. The anteromedial tibial margin (joint line) was used as the cross-sectional reference landmark from which levels of girth measurement were located. This was easily palpated with the knee placed in figure-of-4 position (flexing the knee to 90 degrees with the ipsilateral hip flexed to 45 degrees and fully externally rotated). However, since the length of thigh portion could vary in different individuals, the second reference levels were marked by arbitrarily dividing the distance between the tibial tuberosity (TT) and the anterior superior iliac spine (ASIS) (roughly representing the thigh length) into 16 equal segments.

To facilitate repeated measurements in cross-sectional planes of the thigh, an instrument was custom-made by attaching the plastic tape measure perpendicularly to the longitudinal bar of a T-square ruler (Fig. 1). The segments were spaced at 2-centimeter intervals and spanned for 30 centimeters from the shorter bar. During the measurement, the shorter ruler bar representing the zero reference level will lie behind the pen-marked knee joint line and the longitudinal bar will lie behind and parallel with the thigh axis (Fig. 2).

The first set of examination (method 1) was performed by measuring circumferences in series for both thighs at 2-centimeter intervals from the anteromedial knee joint line proximally until 30 centimeters cephalad. The second set (method 2) was measured by firstly marking levels on both thighs into 16 equal segments between the TT and ASIS. Each level was then measured cephalad at 1/16 ratio; practically from the second up to the eleventh segment, by using the same instrument with some adjustments of the longitudinal ruler bar position to use the closest tape measure. Recorded data from both normal and injured sides were analyzed for statistical significance.

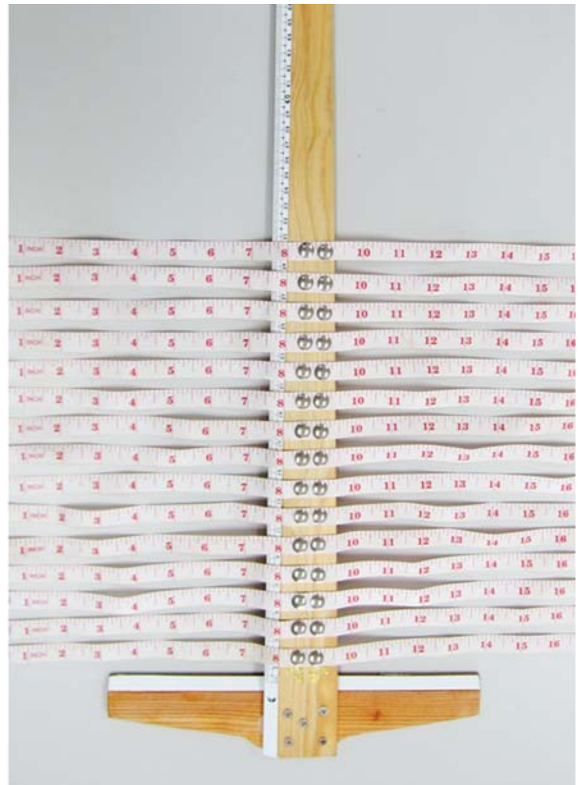

Fig. 1 The customized T-square ruler installed perpendicularly on the longitudinal bar with plastic tape measures at 2-centimeter intervals spanning for 30 centimeters from the shorter bar.

Weight, height, body mass index (BMI) and other demographic data were also collected.

The data from both sets of measurement were calculated for means, standard deviations (SD) and levels of statistical significance by using paired t-test (SPSS® for Windows® version 13.0). Since there were 15 and 10 times of comparison in each sample for methods 1 and 2, respectively; the ANOVA and Bonferroni correction were performed. The p-values should then be less than 0.05/15 = 0.003 and 0.05/10 = 0.005, respectively.

Results

The present study consecutively registered

30 eligible patients sustaining principally unilateral ACL deficiency who were scheduled for ACL reconstruction at Srinagarind Hospital, Faculty of Medicine of Khon Kaen University. Demographic data with spectra of each characteristic are presented in Table 1. Results of measurement for method 1 and method 2 with means, SD and p-values are shown in Tables 2 and 3, respectively. The graphs in Fig. 3 and 4 demonstrate mean thigh circumference difference measured at each level for methods 1 and 2 respectively.

The statistics show that the most relevant levels to measure thigh circumference difference (d) are located at 18 cm ($d = 3.04 \pm 0.91$ cm, $p = 0.001$) and 20 cm ($d = 3.11 \pm 0.81$ cm, $p = 0.002$) above the anteromedial knee joint line or at the 6/16 ratio ($d = 3.13 \pm 0.70$ cm, $p = 0.001$) of the thigh length measured from the TT towards the ASIS.

By regression analysis, the BMI does not have effect on the mentioned results.

Fig. 2 Measuring the thigh using the customized instrument

Discussion

Although volumetric capacity of the thigh does not have strong relationship with quadriceps and hamstring strength(5,12) or their cross-sectional areas(10), manual measurement of the thigh girth using a tape measure is still a common clinical examination to approximate loss of thigh capacity or quadriceps atrophy. Determination of relevant landmarks and levels of measurement in the present study will warrant validity in detecting cross-sectional size difference of the thighs. In present study, recruitment of 30 subjects has strengthened the robustness in estimation. The reason the authors used the anteromedial knee joint line, rather than the patella, as a landmark was due to its relatively definite and superficial anatomy. Another concept of current measurement is estimating the thigh length in ratios marked between the TT and ASIS. This method is more generalized as it is related to the stature of the subject rather than using fixed levels from a fixed body landmark. It is noticeable that the greatest mean thigh circumference differences between the two methods in this study are comparable.

Determining the 6/16 or 3/8 ratio of the thigh

Table 1. Demographic data of the 30 eligible patients with ACL deficiency

Characteristics	Ratio or range	Mean $\pm$ SD*
Sex (Male: Female)	28:2	-
Side (Right: Left)	17: 13	-
Age (year)	17-45	29.03 ± 7.8
Weight (kg)	54-90	65.46 ± 8.66
Height (cm)	155-178	168.59 ± 6.36
BMI (kg/m^2)	18.27-29.27	23.01 ± 2.71
Duration after injury (month)	4-122	21.80 ± 26.97
KT-1000® difference (mm)	4-8	5.83 ± 1.05
Lysholm score	81-93	89.47 ± 3.1

*SD = standard deviation

Table 2. Results of thigh circumference measured at different levels above the anteromedial knee joint line (method 1) in 30 patients sustaining ACL deficiency

Level (cm)	Mean $\pm$ SD* (cm)		p-value
	Normal side	Injured side	
2	38.74 $\pm$ 1.50	38.52 $\pm$ 1.40	0.542
4	39.84 $\pm$ 1.70	39.56 $\pm$ 1.66	0.507
6	41.20 $\pm$ 2.07	40.66 $\pm$ 1.92	0.269
8	42.61 $\pm$ 2.17	41.74 $\pm$ 1.98	0.586
10	44.68 $\pm$ 2.92	43.11 $\pm$ 2.27	0.202
12	46.39 $\pm$ 3.25	44.68 $\pm$ 2.63	0.028
14	48.39 $\pm$ 3.67	46.45 $\pm$ 3.01	0.028
16	50.54 $\pm$ 3.91	47.85 $\pm$ 3.28	0.005
18	52.04 $\pm$ 3.85	48.87 $\pm$ 3.39	0.001
20	53.04 $\pm$ 3.60	49.96 $\pm$ 3.59	0.002
22	53.79 $\pm$ 3.36	51.66 $\pm$ 3.54	0.020
24	54.73 $\pm$ 3.22	52.89 $\pm$ 3.40	0.036
26	55.47 $\pm$ 2.98	53.74 $\pm$ 3.31	0.038
28	56.29 $\pm$ 2.95	54.66 $\pm$ 3.02	0.038
30	56.93 $\pm$ 2.98	55.62 $\pm$ 2.87	0.086

*SD = standard deviation

Table 3. Results of thigh circumference measured cephalad at 1/16 ratio between TT and ASIS (method 2) in 30 patients sustaining ACL deficiency (appropriate measurable levels are between 2/16 and 11/16)

Level (ratio)	Mean $\pm$ SD* (cm)		p-value
	Normal side	Injured side	
2/16	39.29 $\pm$ 1.57	39.03 $\pm$ 1.50	0.515
3/16	42.62 $\pm$ 2.17	41.74 $\pm$ 1.98	0.110
4/16	46.39 $\pm$ 3.25	44.67 $\pm$ 2.63	0.028
5/16	50.54 $\pm$ 3.91	47.84 $\pm$ 3.28	0.005
6/16	52.54 $\pm$ 3.72	49.41 $\pm$ 3.47	0.001
7/16	53.42 $\pm$ 3.47	50.80 $\pm$ 3.54	0.006
8/16	54.26 $\pm$ 3.28	52.27 $\pm$ 3.46	0.026
9/16	55.10 $\pm$ 3.09	53.32 $\pm$ 3.35	0.036
10/16	55.88 $\pm$ 2.95	54.20 $\pm$ 3.16	0.270
11/16	56.62 $\pm$ 2.96	55.14 $\pm$ 2.94	0.057

*SD = standard deviation

length could be approximated as 3/9 or 1/3 the length for simplicity. The resulted discrepancy of the approximation equals 3/8-3/9 = 0.042 or 4.2 percent of the thigh length. In practice, the measurement should be generalized by using a simple tape measure rather than the customized instrument. It is important to apply

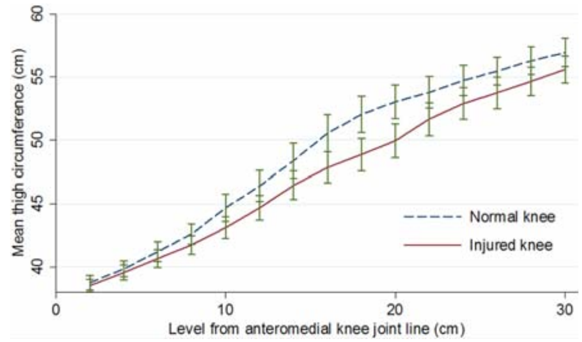

Fig. 3 The graph demonstrating mean thigh circumference and 95% confidence interval measured at each level on the normal and injured sides for method 1

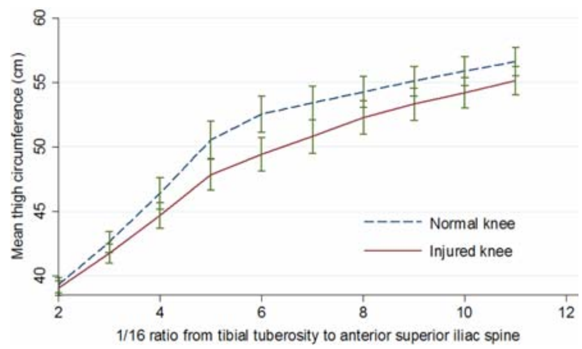

Fig. 4 The graph demonstrating mean thigh circumference and 95% confidence interval measured at each level on the normal and injured sides for method 2

the tape with constant and even tension and place it flat with the skin and square with the long axis of the limb.

The subjects were also estimated for body fat percentage using BMI (optimal weight = 20-25 kg/m^2). There is a study showing significantly higher thigh fat component in the ACL deficient knee than in the intact knee[11], though there is no clear correlation between the body mass and the thigh fat component[13]. In the present study, the BMI does not affect results of the measurements which also indicate that the proposed methods can be used regardless of the individual body mass.

Results of the present study will set a standard guideline for manual thigh girth measurement and likely to help improve accuracy of related clinical assessments. However, since our samples are limited to effects after ACL insufficiency, this can be different to atrophy caused by other conditions not secondary to knee problems such as residual poliomyelitis or abnormal growth and development. Finally, although anatomical landmarks for measurements have been clearly defined, reliability of the measurements still exists to be investigated[14].

Conclusion

In patients with knee problem using deficient ACL as the prototype, the most relevant level to detect thigh girth difference from the normal side is located at 18 cm and 20 cm above the anteromedial knee joint line or at 6/16 (3/8 or approximately 1/3) the thigh length measured from the TT towards the ASIS.

Potential conflicts of interest

None.

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ระดับที่น่าเชื่อถือที่สุดในการประมาณค่าความแตกต่างของเส้นรอบวงระหว่างต้นขาในภาวะขาดเอ็นไขว้หน้า

วิรุฬห์ เหล่าภัทรเกษม เพิ่มศักดิ์ พหลภาคย์ วีระชัย โควสุวรรณ

ภูมิหลัง: *การวัดเส้นรอบวงของต้นขาเป็นเครื่องมือง่ายๆ ที่ใช้ประเมินความเปลี่ยนแปลงขนาดของต้นขา อย่างไรก็ตาม ยังไม่มีหลักฐานเชิงประจักษ์ว่าได้กำหนดตำแหน่งใดทางกายวิภาคที่น่าเชื่อถือที่สุดในการตรวจหาความแตกต่างของเส้นรอบวงของต้นขาโดยเทียบกับข้างปรกติ*

วัสดุและวิธีการ: *การศึกษานี้ใช้ผู้ที่เอ็นไขว้หน้าขาดข้างหนึ่งเป็นต้นแบบ โดยได้ทำการวัดระยะรอบต้นขาทั้งสองข้างที่ระยะห่างกันทุก 2 ซม. ตั้งต้นจากแนวข้อเข่าทางด้าน anteromedial จนถึงระดับเหนือขึ้นไป 30 ซม. ในการนี้ยังได้ทำการวัดอีกแบบหนึ่งโดยใช้สัดส่วนในระยะ 1/16 ของความยาวต้นขาที่วัดจาก tibial tuberosity (TT) ไปสู่ anterior superior iliac spine (ASIS)*

ผลการศึกษา: *เมื่อวิเคราะห์ค่าเฉลี่ยและค่าความเบี่ยงเบนมาตรฐานจากผลการวัด พบว่าระดับที่เส้นรอบวงของต้นขาสองข้างมีความแตกแต่งกันอย่างมีนัยสำคัญทางสถิติคือที่ระยะ 18 ซม. และ 20 ซม. เหนือแนวข้อเข่าดังกล่าว หรือตรงสัดส่วนที่ 6/16 (3/8 หรือประมาณ 1/3) ของความยาวต้นขาวัดจาก TT ถึง ASIS*

สรุป: *จากการศึกษาโดยใช้ผู้ป่วยที่ขาดเอ็นไขว้หน้าในข้อเข่าเป็นต้นแบบพบว่า ระดับที่น่าเชื่อถือที่สุดในการวัดเพื่อประมาณค่าความแตกต่างของระยะรอบต้นขาเมื่อเทียบกับข้างปกติคือที่ระยะ 18 ซม. และ 20 ซม. เหนือแนวข้อเข่าทางด้าน anteromedial หรือตรงสัดส่วนที่ประมาณ 1/3 ของความยาวต้นขาวัดจาก TT ถึง ASIS*