Reliability of rehabilitative ultrasound imaging for measuring the gluteus maximus muscle at rest and during contraction

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Objective: The aim of this study was to investigate the inter-rater and intra-rater reliability of rehabilitative ultrasound imaging (RUSI) for measurement of muscle thickness with changes in angles of the gluteus maximus (GM) at rest and during contraction.

Design: Cross-sectional study.

Methods: Twenty-two healthy men volunteered for this study. GM muscle images were obtained in the resting position and during prone hip extension with knee flexion at hip abduction angles of 0° and 30°, respectively. Two examiners randomly measured the thickness of the GM twice in three different positions. The first position was a comfortable prone position. The second position was prone hip extension with knee flexion (PHEKF) to 90°. The third position was achieved by hanging a 1-kg weight on the ankle of the lifted leg during PHEKF with the angle of the lifted leg the same as the second position. Intra-class correlation coefficients (ICCs), standard error measurements, and minimal detectable changes were used to estimate reliability.

Results: The intra-rater reliability ICCs (95% confidence interval) of the GM were >0.870, indicating good reliability. Inter-rater reliability ICCs ranged from 0.668 to 0.913. The reliability of measurements of muscle thickness at each position was similar to the reliability of the angle change. Differences in muscle thickness and ratios for each position with 0° and 30° of hip abduction were not statistically significant.

Conclusions: In the present study, the intra-rater reliability of muscle thickness measurements of the GM was good, and the inter-rater reliability was moderate to good. Reliable RUSI measurements of wide and large muscles, such as the GM muscle at rest and during contraction, are feasible. Further investigation is required to establish the reproducibility of the protocols presented in this study.

Key Words: Gluteus maximus, Muscle thickness, Reliability, Ultrasound

Introduction

Rehabilitative ultrasound imaging (RUSI) has been used advantageously by physiotherapists to measure muscle morphology. RUSI also can provide visual feedback as an exercise guide and can be used to measure both static and dynamic muscle tissue in the state of contraction [1-5]. RUSI has been used to address research and study questions regarding a variety of muscles [6]. Trunk, upper limbs, calf, and shin muscles have been the muscles most frequently researched using RUSI. However, except for one previous in-

vestigation [6], studies utilizing RUSI to assess muscles of the buttocks are lacking.

The gluteal region is composed of the gluteus maximus (GM), gluteus medius, and gluteus minimus muscles. The GM is one of the largest and strongest muscles of the body [1,7]. In particular, the GM functions as a powerful extensor and abductor and is the primary muscle in rehabilitation exercises for low back pain and lower-extremity injuries [8,9]. Furthermore, the GM plays a number of roles in the performance of activities such as walking, running, and lifting, and provides stability to the sacroiliac joint. The GM will affect

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the kinetic chain change of the lower limb due to pain or injury [10]. For pelvic stability and safe and effective movement of the lower limbs, a GM strengthening exercise has been applied for rehabilitation training.

The GM strengthening exercise, prone hip extension with knee flexion (PHEKF) exercise, is a well-known, effective method for activation of the GM muscle during lower limb extension [11]. Recent research on application of the PHEKF exercise has used electromyography (EMG) and measurement of the angle of the leg to assess the activation of the GM [12]. Although many studies have evaluated GM activation using EMG, studies that measured GM activation using RUSI are lacking. An advantage of using RUSI to evaluate static and dynamic conditions of the muscle is reliable measurement of the GM state of change.

The purposes of this study were as follows: first, to establish a protocol to measure the GM muscle using RUSI; second, to determine whether measurement of the GM muscle with RUSI is highly reliable as it is with other muscles; and third, to investigate and compare the difference in muscle thickness as measured by the angle change between resting position and contraction of the GM muscle.

Methods

Subjects

Subjects were 22 young healthy (men recruited) from Sahmyook University students who volunteered to participate in this study. The participants had full, active, pain-free range of motion of prone hip extension with 90° knee flexion. Exclusion criteria were past or present musculoskeletal or neuromuscular disorders affecting the hip region and, history of hip pain in the preceding year. Obese individuals with

body mass index (BMI) of $>30 \text{ kg/m}^2$ were also excluded [13]. The purpose of the study was explained to the participants, and informed consent was obtained. The study was approved by the Institutional Review Board of the Sahmyook University (IRB No. SYUIRB2015-17) in Seoul.

Procedures

An ultrasound imaging system (Medison Myosone U5; Samsung Medison Co. Ltd., Seoul, Korea) with a 12 MHz linear transducer was used to obtain images of the GM muscle. Two examiners randomly measured the thickness of the GM twice in 3 different positions. The first position was a comfortable prone position (resting position). Each position comprised 2 kinds operations: first maintaining the legs side-by-side at 0° on the prone table, then maintaining abduction at 30°. The second position was PHEKF with 90° knee flexion. To achieve this, each participant lifted the dominant leg toward the ceiling until the patella was raised 5 cm off the table. The hip extension was then maintained for 5 seconds [14]. The leg was lifted at both 0° and 30° abduction as performed in the first position. The third position was achieved by hanging a 1-kg weight on the ankle of the lifted leg during PHEKF with the angle of the lifted leg the same as in the second position. Participants were instructed to rest and relax the hip and leg in the test positions. The process was repeated on the dominant side.

Prior to imaging, each participant's gluteal region was exposed in the prone position, and the dominant side was palpated and marked. To create exact RUSI scan protocols for the GM, we referred to previously published musculoskeletal ultrasound guidelines [15]. To determine the transducer placement, the examiners marked 2 lines from dominant side's posterior superior iliac spine to the ischial tuberosity

Figure 1. (A) Position of the probe to measure. (B) Rehabilitative ultrasound image of the GM. GM: gluteus maximus, MT: muscle thickness, IT: ischial tuberosity.

(IT) and an imaginary line perpendicular from the previous line to the IT. The transducer was placed at the point where 2 lines intersected at a right angle (Figure 1A). The image was monitored to assure a continuous picture of the IT visualized at the middle part. The RUSI image showed skin, fat, GM, and IT (Figure 1B). The skin was mildly echogenic, and subcutaneous fat was hypoechoic on the RUSI scan. The GM is located between the IT and the hypo echoic area below the skin. The examiners measured the vertical length between the inferior echogenic fascial line of the skin and the superior hyperechoic region of the IT. In the study, to investigate the angle difference between the positions, the change in muscle thickness at 0° to 30° abduction was calculated, and the ratio of muscle thickness was determined.

Data analysis

Statistical analysis was performed using IBM SPSS

Statistics ver. 18.0 (IBM Co., Armonk, NY, USA). To describe the intra and inter-rater reliability of the GM muscle thickness at rest and during contraction, intra-class correlation coefficients (ICCs) were calculated [13]. Bland-Altman plots and 95% confidence intervals (CIs) were generated to provide a visual representation of muscle thickness to determine the agreement between the 2 measurements. ICC and Bland-Altman plots have been accepted as the statistical methods of choice in reliability studies. ICCs < 0.50 were considered to represent poor, 0.50 to 0.75 moderate, and > 0.75 high reliability [16]. To assess measurement accuracy, standard error of measurement (SEM) was calculated as $\text{standard deviation} \times \sqrt{1 - \text{ICC}}$. The 95% minimal detectable change (MDC) was calculated as $1.96 \times \text{SEM} \times \sqrt{2}$. One-way analysis of variance and independent t-test were used to compare the differences between and ratios of muscle thickness between positions between positions accord-

Table 1. Intra-rater between repeated measures for the gluteus maximus MT

(N=22)

Variable		MT (cm)		ICC	95% CI	SEM	MDC
		1st test	2nd test				
E1	Resting 0°	2.32 (0.58)	2.41 (0.62)	0.938	0.850-0.974	0.150	0.416
	Resting 30°	2.39 (0.67)	2.30 (0.66)	0.925	0.819-0.969	0.182	0.504
	Contraction 0°	3.22 (0.54)	3.24 (0.57)	0.967	0.921-0.986	0.101	0.279
	Contraction 30°	3.20 (0.62)	3.29 (0.71)	0.947	0.872-0.978	0.154	0.149
	Weight 0°	3.19 (0.64)	3.18 (0.69)	0.957	0.896-0.982	0.149	0.413
	Weight 30°	3.32 (0.71)	3.32 (0.73)	0.892	0.739-0.955	0.254	0.705
E2	Resting 0°	2.40 (0.82)	2.37 (0.86)	0.954	0.888-0.981	0.179	0.497
	Resting 30°	2.45 (0.79)	2.40 (0.85)	0.960	0.904-0.983	0.163	0.452
	Contraction 0°	2.80 (0.81)	2.95 (0.63)	0.872	0.691-0.947	0.259	0.718
	Contraction 30°	2.99 (0.65)	3.06 (0.62)	0.984	0.962-0.993	0.081	0.224
	Weight 0°	3.00 (0.71)	2.85 (0.71)	0.903	0.766-0.960	0.221	0.612
	Weight 30°	3.05 (0.65)	3.01 (0.70)	0.951	0.882-0.980	0.150	0.415

Values are presented as mean (SD).

MT: muscle thickness, ICC: intra-class correlation coefficient, CI: confidence interval, SEM: standard error of the measurement, MDC: minimal detectable change, E1: examiner first, E2: examiner second.

Table 2. Inter-rater reliability for gluteus maximus MT of repeated measure

(N=22)

Variable	1st test				2nd test			
	ICC	95% CI	SEM	MDC	ICC	95% CI	SEM	MDC
Rest 0°	0.834	0.600-0.931	0.439	1.217	0.832	0.595-0.930	0.423	1.172
Resting 30°	0.691	0.256-0.872	0.607	1.684	0.764	0.430-0.902	0.440	1.220
Contraction 0°	0.668	0.201-0.862	0.536	1.486	0.686	0.244-0.870	0.512	1.420
Contraction 30°	0.788	0.489-0.912	0.456	1.265	0.721	0.327-0.884	0.485	1.343
Weight 0°	0.864	0.673-0.944	0.385	1.066	0.833	0.597-0.930	0.385	1.068
Weight 30°	0.755	0.409-0.898	0.494	1.370	0.913	0.791-0.964	0.277	0.767

MT: muscle thickness, ICC: intra-class correlation coefficient, CI: confidence interval, SEM: standard error of the measurement, MDC: minimal detectable change.

Figure 2. Bland-Altman plots illustrating the difference of rehabilitative ultrasound image for the gluteus maximus muscle between examiner 1 and 2 during the rest and contraction, weight contraction position for interrater reliability. (A) Resting position 0° measurement. (B) Resting position 30° measurement. (C) Contraction position 0° measurement. (D) Contraction position 30° measurement. (E) Weight contraction position 0° measurement. (F) Weight contraction position 30° measurement. SD: standard deviation.

ing to angle changes. Statistical significance was set at $p < 0.05$.

Results

Demographic characteristics

Characteristics of the participants were as follows: 22 healthy male participants with mean age 23.90 ± 2.48 years, mean weight 64.72 ± 9.01 kg, and mean height 172.04 ± 5.71 cm. The mean BMI and thigh circumference were 21.79 ± 2.34 kg/m² and 55.35 ± 5.06 cm, respectively.

Intra-rater reliability analysis

A summary of the results for the intra-examiner reliability of the GM muscle thickness and positions for the 2 sessions performed by 2 examiners is shown in Table 1. The ICCs for intra-rater reliability ranged from 0.872 to 0.984 and the CI was within an acceptable range of 0.739 to 0.986. The SEM values ranged from 0.081 to 0.259 cm, and the MDC values ranged from 0.149 to 0.718 for the GM.

Inter-rater reliability analysis

The ICCs for inter-rater reliability ranged from 0.668 to 0.913 (Table 2). The SEM values ranged from 0.277 to 0.607 cm, and the MDC values ranged from 0.767 to 1.684. Bland-Altman plots for inter-rater reliability between examiners are shown in Figure 2.

Ratio and difference of muscle thickness during positions

No statistically significant differences were observed between 0° and 30° angle change positions (Table 3). No significant difference was seen in muscle thickness ratios for the 2 positions. However, the muscle thickness difference between 0° and 30° tended to increase in the more contracted state of 30° abduction.

Table 3. The ratio and difference of muscle thickness on the gluteus maximus muscle according to the angle change (N=22)

MT (cm)	Ratio	Difference	p
Position			
Resting 0°-30°	1.03 (0.17)	0.04 (0.42)	0.726
Contraction 0°-30°	1.08 (0.22)	0.15 (0.35)	0.081
Weight 0°-30°	1.04 (0.08)	0.11 (0.23)	0.068
p	0.551	0.594	

Values are presented as mean (SD).
MT: muscle thickness.

Discussion

The GM muscle makes a large contribution to gait, effective lower limb movement, and pelvic stability [10]. In our study, the GM muscle was measured using RUSI. RUSI is a non-invasive, accessible, safe, and low-cost tool that is particularly effective for muscle size measurement [1]. Taking into account the direction (inferolateral) and point of attachment of the GM muscle fibers [7,17], we measured its thickness at angles of 0° and 30° abduction for each position. Furthermore, we modified existing musculoskeletal ultrasound guidelines [15] to develop a GM measurement protocol. Among the body's muscles, the GM is the largest, and its contraction results in a large volume change. Therefore, to accurately represent the landmark muscle, it was subjected to measurement in the same way for all participants.

In a previous study, in which the gluteus medius and minimus muscles were measured, intra-rater ICC achieved high reliability (all ICCs > 0.83) [6]. In our study, RUSI of GM muscle thickness produced a good intra-rater reliability (E1 ICCs, 0.892 to 0.967; E2 ICCs, 0.872 to 0.960), but inter-rater reliability was moderate to good (1st ICCs, 0.668 to 0.864; 2nd ICCs, 0.686 to 0.913). All 3 experimental conditions (resting, PHEKF, and PHEKF+1-kg weight) exhibited similar 95% CI and ICCs. Inter-rater reliability was lower than intra-rater reliability. Reliability indices were similar for intra-rater, inter-rater, same-day, and separate-day measurement of muscle thickness with RUSI. By contrast, in English *et al.*'s study [18], the reliability of posterior lower leg muscle thickness was moderate (intra-rater reliability = 0.70 – 0.71), and in Talbott and Witt's study of the reliability of serratus anterior muscle thickness, inter-rater reliability at rest and during contraction was poor (ICCs, 0.425 to 0.526). Compared with the reliability of thickness of the abdominal muscles, which contract under relatively static conditions [19,20], the reliability of thickness of muscles that contract under dynamic conditions is lower [13]. SEMs of intra-rater reliability for both the first and second examiner were similar (E1 SEM, 0.101 to 0.254 cm; E2 SEM, 0.081 to 0.259 cm), whereas SEM values of inter-rater reliability (SEM, 0.385 to 0.607 cm) were higher.

Muscle thickness was found to be greater at 30° than at 0° hip abduction, but the difference was not statistically significant. Similarly, no significant difference was observed even when muscle thickness was compared with the ratio increase. However, in the weight contraction, muscle thick-

ness tended to be thicker. This study was designed to assess results at angles of 0° and 30° hip abduction in accordance with the findings of Kang *et al.* [12] study. In Kang *et al.*'s study of muscle contraction with hip abduction of 0°, 15°, and 30° during PHEKF exercise, GM muscle activation at 30° abduction increased significantly ($p < 0.001$). However, the EMG measurement point in that study was in the upper fibers of the GM, whereas in our study, the ultrasound measurement point was in the lower fibers. The GM's lower fibers play a greater role in hip abduction extensor force compared with that of the upper fibers [21]. Changes in the muscle in regard to angle of abduction in the present study did not significantly increase muscle thickness beyond that expected as a result of the contracting force of hip extension. In consideration of the fiber arrangement of the GM, it was necessary to create a RUSI protocol that used measurements of the upper fibers. In addition, the difference in muscle thickness due to different angles of abduction affected the sample size and significance of results.

This study had several limitations. First, all participants were young males. Second, the sample size was small. Third, the accuracy and reproducibility of the results need to be confirmed because the experimental protocol of the study has never been used before. Fourth, because the GM is a large and bulky muscle, it is necessary to control the conditions under which its contraction can be measured.

This study demonstrates that GM muscle thickness can be measured reliably using RUSI. However, as in measurement of other muscles, intra-rater reliability was higher than the inter-rater reliability in measurement of GM muscle thickness with RUSI. Further experimentation is needed to increase the reproducibility of RUSI results. Nevertheless, in patients with limping gait or severe muscle atrophy, measurement of GM thickness may be useful. Thus, application of the research may widen the practical use of RUSI.

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Conflict of Interest

The authors declared no potential conflicts of interest with respect to the authorship and/or publication of this article.

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