SHORT COMMUNICATION

Measurement posture influences acute changes in quadriceps muscle thickness following resistance exercise

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Objectives: To compare acute exercise-induced changes in anterior and lateral quadriceps muscle thickness (MT) measured in standing and supine positions.

Design: Repeated-measures experimental study.

Methods: Fifty healthy adults (18–35 years) performed four sets of unilateral knee extensions to task failure at 70% of one-repetition maximum (1RM). B-mode ultrasound was used to measure anterior and lateral quadriceps MT before and immediately after exercise in standing and supine positions. Measurements were obtained from both the exercised and contralateral control limbs.

Results: Anterior thigh MT increased by 0.95 cm in the supine position and 0.68 cm in the standing position following exercise (both $p < 0.001$), with the increase being greater in the supine position (mean difference = 0.26 cm, $p < 0.001$). Lateral thigh MT increased by 0.32 cm in the supine position and 0.48 cm in the standing position (both $p < 0.001$), with the increase being greater in the standing position (mean difference = 0.15 cm, $p < 0.001$). No significant time effects were observed in the control limb for either site (both $p > 0.05$).

Conclusions: Measurement posture influenced both baseline quadriceps MT and the magnitude of acute exercise-induced changes. Anterior thigh MT increased more in the supine position, whereas lateral thigh MT increased more in the standing position. These findings highlight the importance of standardizing measurement posture when interpreting ultrasound-derived changes in quadriceps MT.

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Keywords: ■ muscle size ■ ultrasound ■ posture ■ acute swelling

INTRODUCTION

When measuring changes in skeletal muscle size, B-mode ultrasound has emerged as an inexpensive, practical, and validated alternative to gold-standard measures such as MRI[1] or CT.[2] Within the resistance training literature, skeletal muscle is most commonly quantified using muscle thickness (MT). Despite widespread use, ultrasound methodology remains poorly standardized. Differences in ultrasound probe type, measurement site, and participant posture may all influence MT measurements. Of these, posture (standing vs. supine) is one of the simplest factors to standardize. Previous research has demonstrated that posture significantly affects MT outcomes. Yasuda et al.[3] and Thoirs and English[4] both reported greater anterior thigh MT values in the standing compared with the supine position. Although posture clearly influences MT measured at a single time point, its effect on changes in MT over time remains unclear.

A 2023 review from our research group noted inconsistencies in the magnitude of muscle growth reported across resistance training studies,[5] with some showing relatively modest changes and others reporting substantially larger increases. One potential contributor to these discrepancies is differences in measurement posture, as some studies assess MT in a supine position[6,7] while others use a standing position[8] at the time of measurement. Often, studies omit measurement posture entirely from their methods, making it impossible to determine whether observed changes were affected by positional factors.[9,10,11] These differences may influence outcomes due to factors such as fluid shifts when lying down or variability in measurement consistency between positions.[12] While posture has been shown to affect MT at a single time point[3,4] it remains unclear whether it also influences a measured change in MT.

Recently, our research group has used acute resistance exercise-induced muscle swelling to evaluate ultrasound measurement techniques.[13,14] Acute muscle swelling provides a useful model for this purpose because it produces a relatively large change in MT over a short period of time, allowing measurement methodologies to be compared under conditions in which a measurable change is expected. The purpose of the present study was to compare pre- to post-exercise changes in MT at the anterior and lateral quadriceps, measured in both the standing and supine positions, and to determine whether posture influenced the magnitude of the observed changes in

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MT. We hypothesized that the magnitude of observed change in MT would be greater when measured in the standing position compared to the supine position.

METHODS

Participants

50 men and women between the ages of 18-35 were recruited to participate in the present study. To be eligible for participation, participants were required to: a) be free from any musculoskeletal disorders or issues preventing strength testing/exercise, b) answer "No" to all questions on the Physical Activity Readiness Questionnaire (PAR-Q), c) have no orthopedic problems preventing strength testing/exercise, d) not having exercised in the past 24 hours, that is performing structured resistance training or intense cardiovascular exercise (e.g., running, cycling), and not have performed structured resistance training targeting the quadriceps within 48 hours of testing. Normal activities of daily living, including walking, were not restricted, and e) not be pregnant or planning to become pregnant. Participants were informed of all benefits and risks of the present study before signing an institutionally approved written informed consent form. The study was conducted in accordance with the standards of the ethics committee and review board of the University of South Florida.

Study Overview

Participants completed one laboratory visit. After completing the inclusion/exclusion questionnaire, PAR-Q, and informed consent, height and body mass were measured. B-mode ultrasound images of the anterior and lateral quadriceps were obtained in standing and supine positions before unilateral knee extension 1RM testing. Participants then performed 4 sets of unilateral knee extensions to task failure with the right leg. Immediately following exercise, ultrasound measurements were repeated at the same sites in both postures. The left leg served as a non-exercise control. Post-exercise measurements were counterbalanced such that participants were alternately assessed first in either the standing or supine position.

Height/Body Mass

Height and body mass were measured using a standard scale and stadiometer.

Ultrasound Imaging

B-mode ultrasound (Mindray DP50, Shenzhen, China) images of the anterior and lateral quadriceps were obtained in both standing and supine positions. Participants were marked at 50% of the distance between the greater trochanter and the lateral femoral condyle. In the standing position, participants stepped onto an outlined foot pad. Likewise, when lying supine, participants had a ball placed between their feet to standardize foot placement during pre- and post-exercise measurements. The probe was coated with transmission gel and held lightly against the skin. Duplicate images were obtained at each site and stored for later analysis. MT was determined as the average distance between the muscle-bone and muscle-adipose interfaces in the 2 stored images, measured to the nearest 0.01 cm.

One Repetition Maximum (1RM)

Participants performed unilateral knee extension exercise with progressively increasing loads until reaching their 1RM. Testing was performed on the right leg only. Between 1RM attempts, each participant was instructed to rest for as long as they desired between 2 and 5 minutes. The 1RM was accurate to the nearest 1.4 kilograms.

Exercise Bout

Participants performed 4 sets of unilateral knee extensions to task failure using an initial load of 70% of 1RM. Loads were adjusted between sets to maintain 8-12 repetitions, with 2-minute rest intervals. Standardized verbal encouragement was provided throughout.

Analysis

All statistical analyses were performed using the IBM SPSS Statistics Version 31.0 software package (IBM Corp., Armonk, NY, USA). Descriptive statistics are presented as mean ± standard deviation (SD). Mean change scores are additionally reported with 95% confidence intervals (CI). Statistical significance was set a priori at $p \leq 0.05$. Separate 2×2 repeated-measures analyses of variance (ANOVA) were used to examine changes in MT of the anterior and lateral thigh musculature. Factors included condition (standing vs. supine) and time (pre- vs. post-exercise). Significant interactions were followed with pairwise comparisons to identify within-condition changes over time and between-condition differences in change scores. To evaluate measurement stability, the non-exercised contralateral limb served as a control condition. Separate 2×2 repeated-measures ANOVAs were also performed on the control limb to assess potential changes over time and between body positions in the absence of exercise. Minimal detectable change (MDC) values were calculated from the control limb using the equation: 1.96 times the standard deviation of the difference between the "pre" and "post" time-matched time points in the control leg (Weir 2005). Finally, to assess differences in reliability using the control condition, CV scores were calculated for each participant and a paired samples t-test was used to compare standing vs. supine.

RESULTS

Demographics

Descriptive data are presented as mean (SD) and displayed in (Table 1). When mean change scores are reported, 95% CI are provided. Fifty individuals were recruited and completed the present study.

Exercise-Induced Changes in Muscle Thickness (Exercise Limb)

There was a significant condition (Supine vs. Standing) by time (pre vs. post) interaction for both the anterior thigh

Table 1. Participant demographics

N = 50	MEANS (SD)
AGE (YRS)	21.7 (2.4)
SEX (M / F)	29 / 21
HEIGHT (CM)	169.5 (11.7)
BODY MASS (KG)	77.4 (22.2)
1RM (KG)	83.3 (28.4)
AVERAGE REPS PER SET	9.6 (2.5)

Abbreviations: 1RM = one-repetition maximum strength

(p<0.001) and the lateral thigh (p=0.002), indicating that the magnitude of the exercise-induced increase in MT differed between positions at both sites. For the anterior thigh, MT increased from pre to post exercise in both the supine [mean change=0.95 (0.84-1.05) cm, p<0.001] and standing positions [mean change=0.68 (0.61-0.76) cm, p<0.001], and this increase was significantly greater in the supine position [mean difference=0.26 (0.16-0.36) cm, p<0.001]. For the lateral thigh, MT similarly increased from pre to post exercise in both the supine [mean change=0.32 (0.23-0.41) cm, p<0.001] and standing positions [mean change=0.48 (0.39-0.56) cm, p<0.001]; however, in contrast to the anterior thigh, this increase was significantly greater in the standing position [mean difference=0.15 (0.06-0.25) cm, p<0.001].

Control Condition (Non-Exercise Limb)

In the non-exercised control limb, there was no condition by time interaction for either the anterior thigh (p=0.29) or the lateral thigh (p=0.43), and no main effect of time at either site (p=0.06 and p=0.14, respectively), confirming that MT did not change over the testing session in the absence of exercise. There was, however, a significant main effect of condition (position) at both sites. Anterior thigh MT was greater in the standing position relative to supine [mean difference=0.67 (0.52-0.81) cm, p<0.001], whereas lateral thigh MT was greater in the supine position relative to standing [mean difference=0.33 (0.18-0.49) cm, p<0.001]. Pre and post muscle thickness values for the exercise and control conditions are provided in Figure 1.

Reliability

The minimal detectable change (MDC), calculated from the control limb, was 0.27 cm and 0.22 cm for the supine and standing positions, respectively, at the anterior thigh, and 0.28 cm and 0.20 cm for the supine and standing positions, respectively, at the lateral thigh. Percent CV was significantly higher in the supine position compared to standing at both the anterior thigh (2.9% vs. 1.7%, p=0.017) and lateral thigh (3.4% vs. 2.2%, p=0.003).

DISCUSSION

Results of the present study suggest that acute changes in MT were observed in both the lateral and anterior thigh when taken in both the standing and supine position. In the anterior quadriceps, greater baseline measurements were observed in the standing position than in the supine position. However, the anterior quadriceps showed greater acute changes when in the supine position compared to standing. In the lateral quadriceps, greater baseline measurements were observed in the supine position than in the standing position. However, greater acute changes were observed in the lateral quadriceps when standing compared to lying in the supine position. Our findings suggest that posture may affect both the baseline muscle size and observed change in MT in the anterior and lateral quadriceps.

Our results suggest that posture may impact muscle thickness at a single timepoint at both the anterior and lateral muscle sites. D'Lugos et al.[15] similarly found anterior quadriceps MT to be significantly greater in standing versus supine (p=0.04). The present findings agree with previous research and provide insight into how posture differentially affects the anterior vs. lateral quadriceps in the standing and supine positions. Specifically, we observed larger MT values in the supine position for the lateral thigh measurement. Thus, it seems that the impact of posture on MT is dependent on the measurement site.

Results of the present study also provide insight into the impact of posture on the observed change in MT. For example, when examining the anterior thigh, although the baseline MT was larger in the standing position than in the supine position, the change in MT was greater in the supine position than in the standing position [mean difference=0.26 (0.16-0.36) cm, p<0.001]. Interestingly, the findings were reversed in the lateral thigh, with a greater baseline MT in the supine position, but a greater change observed in the standing position [mean difference=0.15 (0.06-0.25) cm, p<0.001]. This site-specific pattern may reflect underlying architectural differences between the rectus femoris and vastus lateralis muscle, which could influence how posture-related, gravity-dependent fluid shifts are distributed within each muscle following exercise. This finding may have important implications when interpreting changes in MT. For example, a 0.7 cm increase in the lateral thigh would be very impressive measured in the supine position; however, it may be viewed as less impressive if measurements were taken in the standing position. Although we recognize that our study design used exercise-induced swelling as a model for detecting change in MT, we believe that our findings may add nuance to how muscle growth studies may be interpreted. Importantly, measurement reliability also appeared to differ by posture, with

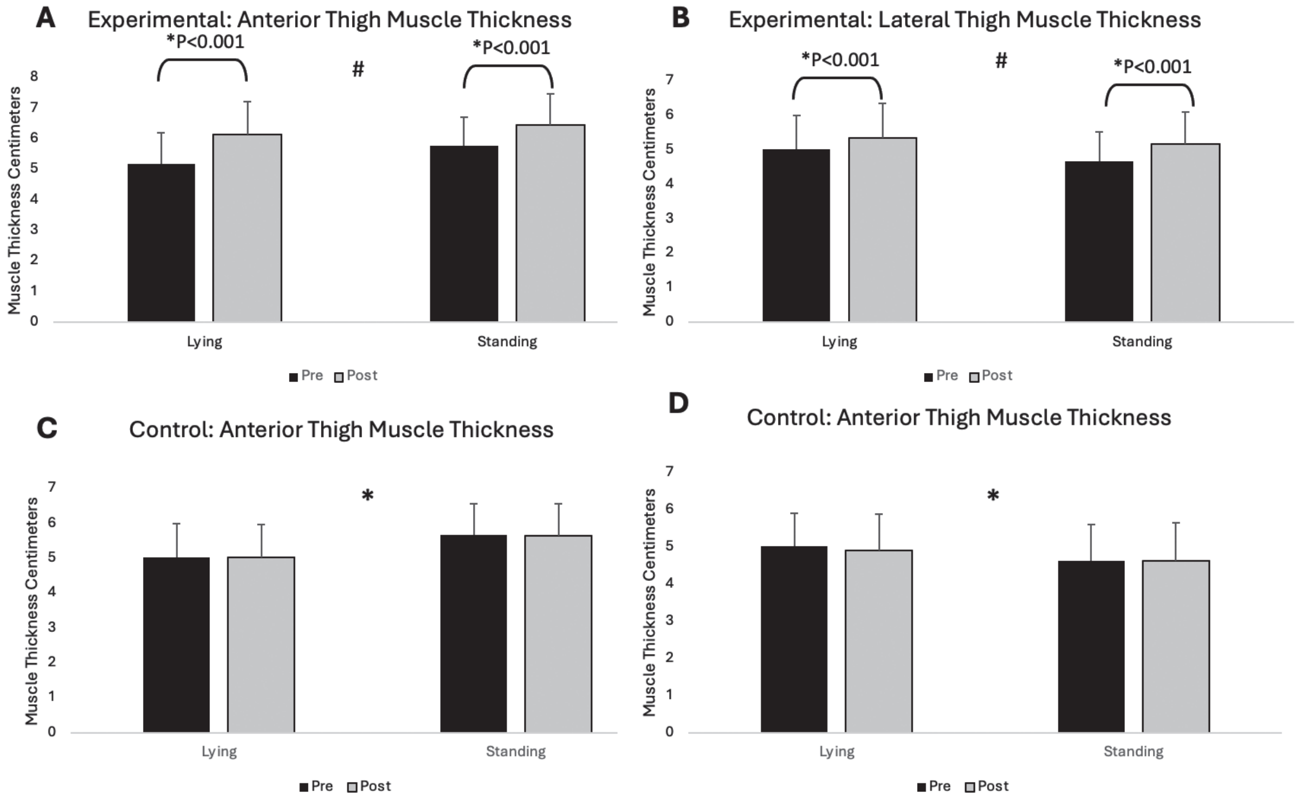

Figure 1. Changes in MT of the anterior and lateral thigh musculature measured in standing and supine positions before and after exercise. Figure 1A and B display the exercised limb for the anterior and lateral thigh, respectively, while 1C and D display the control limb. In the exercised limb, an asterisk* indicates a significant increase from pre- to post-exercise ($p < 0.001$), and # indicates a significant condition × time interaction ($p < 0.05$). In the control limb, # indicates a significant main effect for condition between standing and supine positions ($p < 0.05$). Data are presented as mean ± SD.

lower CVs and MDC values generally observed in the standing position. Thus, differences in posture may influence not only the magnitude of an observed change in MT, but also the variability associated with detecting that change.

The present study is not without limitations. We examined only the anterior and lateral quadriceps; therefore, these findings may not extend to other muscle groups. In addition, acute exercise-induced changes in MT were examined rather than chronic hypertrophy, and it remains unclear whether similar posture-related differences would occur following long-term resistance training. Post-exercise measurements were obtained within 30 seconds and the initial measurement position was alternated between participants to minimize order effects. Lastly, our study measured exercise-induced swelling as a method to yield a change in MT. Application to muscle growth studies should be done with extreme caution. Despite these limitations, this study provides important insight into the influence of posture on ultrasound-derived changes in MT.

CONCLUSION

The present study compared changes in MT measured in the standing and supine position. The primary finding indicated that anterior MT changes were greater measured in the supine position, whereas lateral thigh MT changes were greater in the standing position. These findings may add important nuance to the interpretation of studies that have measured muscle in different postures.

CONFLICTS OF INTEREST

None

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