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Impact of forearm pronation on ultrasound-measured forearm muscle thickness in children and adolescents

IMAGING

SHORT COMMUNICATION

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ABSTRACT

Background and Aim: It was unknown whether ultrasound-measured forearm muscle thickness was impacted by pronation of the forearm. The aim of this study was to investigate the influence of forearm pronation on two forearm muscle thicknesses (MT-ulna and MT-radius).

Participants and Methods: Fourteen healthy children and adolescents sat on a chair with their right arm comfortably on a table, and their hands were fixed to the board with elastic bands. The probe was placed perpendicularly over the forearm, and the angle of the board was then pronated in 5° increments from −10° to 30°. The average value of the two measures at each angle was used.

Results: There was evidence that MT-ulna differed across measurement sites ($F = 51.086$, $P < 0.001$). For example, the values of the MT-ulna were 2.58 (SD 0.40) cm in standard position (0°), 2.56 (SD 0.41) in −10°, 2.62 (SD 0.41) in 10°, 2.65 (SD 0.42) in 20°, and 2.71 (SD 0.43) in 30°. Follow-up tests found that all sites differed from each other except for −10° and −5° ($P = 0.155$) and 10° and 15° ($P = 0.075$). There was also evidence that the MT-radius differed across measurement sites ($F = 22.07$, $P < 0.001$). Follow-up tests found that many but not all sites differed from each other.

Conclusion: Our results suggest that MT-ulna increases and MT-radius decreases due to forearm pronation from the standard position (0°). When determining the forearm position using the 95% limits of agreement, we recommend the forearm position within ±5° of the standard forearm position when measuring forearm MT.

KEYWORDS

B-mode ultrasound, forearm muscle thickness, forearm pronation

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Introduction

Ultrasound is a useful imaging technique to assess the subcutaneous adipose tissue and muscle sizes of the upper and lower extremities and the trunk [1, 2]. In larger human muscle, however, a single ultrasound image can measure only muscle thickness (MT), not muscle cross-sectional area or muscle volume. In addition, approximately 20 muscles are placed around the two bones of the forearm, and two major extrinsic flexor muscles of the fingers, i.e., flexor digitorum profundus and flexor digitorum superficialis, are located near the ulna of the upper portion of the forearm [3]. However, there are various shapes in those two muscles, and the boundary surrounding those two muscles is not visualized with the ultrasound [4]. Therefore, MT may be desirable when assessing the muscle size of the extrinsic forearm flexor muscle of the fingers, although those are relatively small-sized muscles. In forearm-supination, the radius is parallel to the ulna, whereas the radius crosses the ulna in the pronation of the forearm. Thus, setting the forearm in the pronation or supination during ultrasound measurement may change the MT. Unlike adults, it may not be possible to maintain the forearm-position during ultrasound measurements in young children.

Previous studies have provided inconsistent conditions on forearm-position during ultrasound measurements. For example, some studies do not describe the forearm-position during ultrasound measurements [5–9]. Studies from our group and others have stated that the forearm MT was measured while participants were standing or supine with the forearm-supinated [10–13]. However, if the measured value of forearm MT changes when the degree of supination of the forearm is slightly different, the accurate ultrasonic measurement will not be possible. For example, if the value differs then estimations of appendicular lean mass from MT of the forearm may lead to erroneous results if the assessment is made in a position different from the original validation [10, 14]. It could also impact the comparison across studies. Therefore, it is important to better understand the influence of forearm-pronation on MT values of the forearm. In the present study, we investigated the impact of forearm-pronation on ultrasound-measured forearm MT in children and adolescents.

Participants and methods

Participants

In this study, fourteen healthy volunteers (6 females) aged 3–11 years [mean age, 7.6 (SD 2.3) years old] were recruited through printed advertisement and by word of mouth. Exclusion criteria were as follows: history of surgery of the upper limbs, cardiometabolic, orthopedic, and neuromuscular diseases. Volunteers with their parents were fully informed about the purpose of the study and its safety and written informed consent was obtained from the parents of each volunteer. This study was approved by the University's Institutional Review Board (HSS-#29-17) and complies with the Helsinki Declaration.

Forearm MT measurements

Participants rested on a chair with their right arm comfortably on a table at an elbow joint angle of approximately 10° (0° at full extension) and their forearm supinated. Additionally, an expanded polystyrene board (7-mm thickness) was placed between the forearm and the table, and the four fingers except for the thumb and the palm were fixed to the board with elastic bands (Fig. 1). The board was separated into two parts (one panel on the forearm and another on the hand), and the top (on which the hand rested) was designed to rotate.

A B-mode ultrasound (Logiq-e; GE, Fairfield, CT, USA) was used to take a total of 18 ultrasound images (9-images, twice) at the anterior forearm. The ultrasound images were taken at 30% proximal of the distance between the styloid process and the head of the radius. The forearm-pronation was assessed using a small electronic level with a digital readout (Level Box, UJK technologies, USA) attached to the top of the panel. The electronic level was first calibrated for each individual, and 0° (standard position) was determined to be when the two panels on the forearm and hand were flat (as illustrated in Fig. 1). The probe was coated with a transmission gel and placed perpendicular over the forearm, and the angle of the panel which on the hand rested was then pronated in 5° increments from −10° to 30°, and the first image was always taken at −10°. One image at each angle was stored in the ultrasound. The probe was never taken off the surface of the skin until all images were taken (a total of 9-images). Two MTs were determined as the perpendicular distance between the subcutaneous adipose tissue-muscle interface and muscle-bone interface of the ulna (MT-ulna) and radius (MT-radius). The distance between the two interfaces was measured with an electronic caliper of the ultrasound. Each individual performed this series of measurements twice to assess MT change, and the average value of the two measures at each angle was used for data analysis.

Reliability of forearm muscle thickness measurements

Test-retest reliability of MT-ulna and MT-radius measurements using the intraclass correlation coefficient ($\text{ICC}_{3,1}$), standard error of measurement, and the minimal difference (i.e. absolute reliability) was determined for data from a different group of 13 children (7 boys and 6 girls, age range 3.9–6.5 years) measured twice, four weeks apart before the study. The measurements were performed in the morning (9:30–11:00 am) using the same methodological protocols described above, and the forearm-position was 0°.

Statistical analysis

All statistical analyses were completed using jamovi (The jamovi project version-1.6.23). The individual plot figures were created using JASP version-0.16. Test-retest reliability was determined by calculating the difference between the value from the initial test to that of the retest. The standard deviation (SD) of that difference was divided by the square root of 2 in order to calculate the standard error of the measurement. The minimal difference (i.e. absolute reliability) was calculated by multiplying the SD of the difference by 1.96. Limits of agreement (95% level) were set by adding and subtracting the minimal difference value from the mean difference.

Differences in MT between sites were determined using a one-way repeated measures ANOVA. If there was a significant overall test, follow-up pairwise comparisons were made in order to determine where the differences were. Statistical significance was set at ≤ 0.05, however, more emphasis was placed on the size of the difference and the

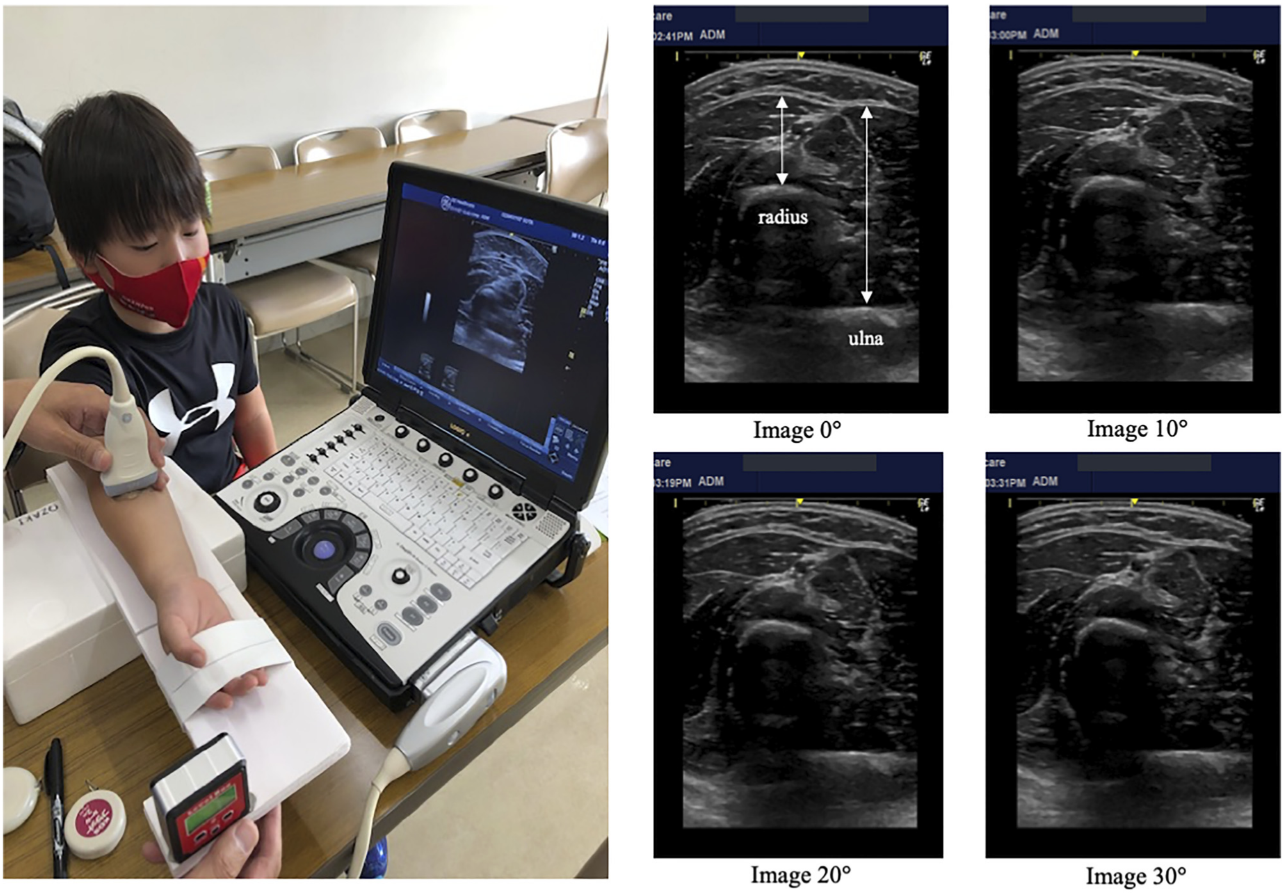

Image 0° Image 10°

Image 20° Image 30°

Fig. 1. Experimental setup used in this study. An expanded polystyrene board (7 mm thickness) was separated into two parts, and the top (on which the hand rested) was designed to rotate. The electronic level (bottom left of the photo) was first calibrated for each individual, and 0° was a parallel of the two boards on the forearm and hand. The ultrasound probe was never taken off the surface of the skin until all images were taken. The right side of the figure is a typical ultrasound image at each angle

variability of that difference. Differences from "0°" with 95% limits of agreement were plotted to visually show agreement across sites.

Results

Change in muscle thickness by forearm pronation

There was evidence that MT-ulna differed across measurement sites ($F = 51.086$, $P < 0.001$). For example, the values of the MT-ulna were 2.58 (SD 0.40) cm in standard position (0°), 2.56 (SD 0.41) in −10°, 2.62 (SD 0.41) in 10°, 2.65 (SD 0.42) in 20°, and 2.71 (SD 0.43) in 30°. Follow-up tests found that all sites differed from each other (Fig. 2A) except for −10 and −5 ($P = 0.155$) and 10 and 15 ($P = 0.075$). There was also evidence that the MT-radius differed across measurement sites ($F = 22.07$, $P < 0.001$). For example, the values of the MT-radius were 1.24 (SD 0.24) cm in standard position (0°), 1.28 (SD 0.27) in −10°, 1.22 (SD 0.24) in 10°, 1.21 (SD 0.23) in 20°, and 1.19 (SD 0.23) in 30°. Follow-up tests found that many but not all sites differed from each other (Fig. 2B). Limits of agreement for each site compared with "0" is illustrated in Fig. 3A for the ulna and Fig. 3B for the radius.

Test-retest reliability

A paired *t*-test revealed no significant differences between test [2.26 (SD 0.5) cm] and retest [2.25 (SD 0.16) cm] for MT-ulna and between test [1.07 (SD 0.10) cm] and retest [1.03 (SD 0.11) cm] for MT-radius. The mean difference was 0.005 (SD 0.031) cm for MT-ulna and 0.035 (SD 0.04) cm for MT-radius. The correlation coefficient between the two measurements was 0.981 and 0.936, respectively. The standard error of measurement and the minimal difference was 0.022 and 0.061 cm for MT-ulna and 0.028 and 0.078 cm for MT-radius. The 95% limits of agreement were −0.050 to 0.065 cm and −0.04 to 0.11 cm, respectively.

Discussion

The current study investigated the impact of forearm pronation on ultrasound-measured forearm MT in children and adolescents. Our results showed that forearm MT-ulna and MT-radius differed across measurement sites, i.e. MT-ulna increases and MT-radius decreases due to forearm pronation from the standard position (0°). The standard position of the forearm in this study was set as a participant sitting on a

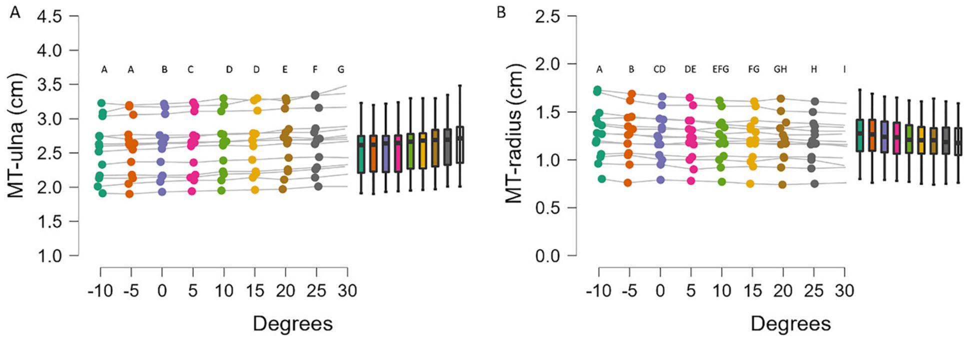

Fig. 2. Individual muscle thickness values at each site for the ulna (panel A) and radius (panel b). The box plot represents the interquartile range of the muscle thickness at each specific degree (−10 to 30°). Letters indicate significant differences between sites. If conditions share the same letter they are not different from one another. Alpha level = 0.05

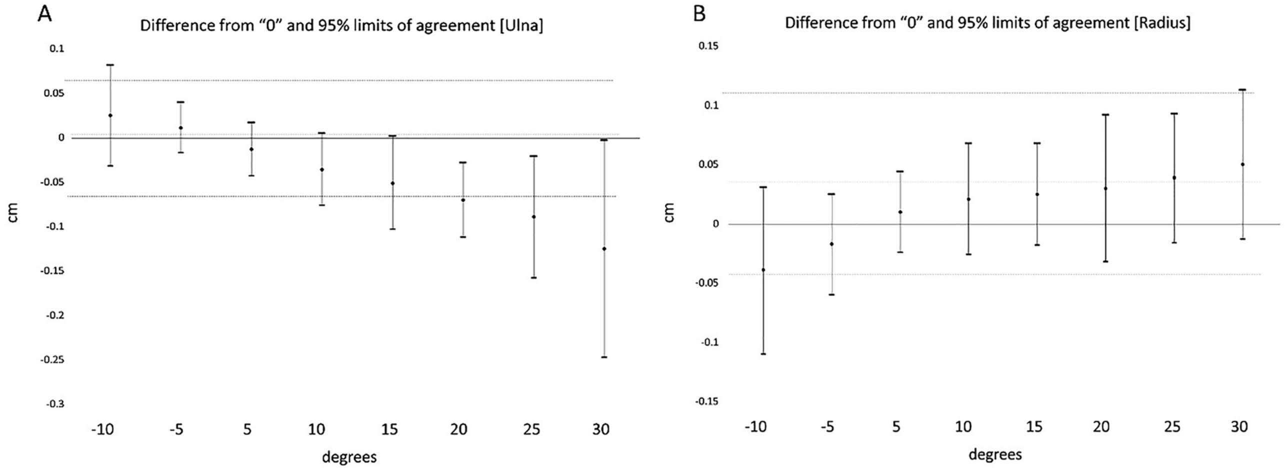

Fig. 3. The differences in forearm muscle thickness (cm) from the standard position (0° minus the value at the other site) and 95% limits of agreement at each angle of the forearm pronation (panel A, ulna; panel B, radius). Notably, the test-retest data is included on the figure as dotted lines to show how the current difference compares with the agreement from the same site measured twice. The middle-dotted line represents the bias between test-retest and the upper and lower dotted lines represent the upper and lower bounds

chair with one arm forward and palms up, and the hand was parallel to the desk. Therefore, when measuring forearm MT using ultrasound, it is necessary to set all participants with the same forearm-position.

Previous studies [5–9] did not describe clear conditions for forearm-position during ultrasound measurements. In our experience, it is not always possible to maintain the forearm-position when testing in a non-laboratory setting such as a pre-school. In the current study, the participants had their hands fixed to a dedicated board using elastic bands and were instructed not to move their upper bodies during the ultrasound measurements. The same ultrasound image is generally used to analyze two forearm MTs together, i.e., MT-ulna and MT-radius. The limits of agreement suggest that values plus/minus 5 degrees of the standard position produce reasonable estimates for both the MT-ulna and MT-radius. The error starts to increase when going beyond this point of rotation.

In conclusion, our results showed that forearm MT differed across measurement sites, i.e. MT-ulna increases and MT-radius decreases due to forearm pronation from the standard position (0°). When determining the forearm-position using the 95% limits of agreement, our results recommended the forearm-position within ±5° of the standard position of the forearm when measuring forearm MT.

Authors' contributions: Conceived and designed the study: TA, HO, AA, and JPL. Performed the data collection: TA, HO, and AA. Analyzed the data: TA and JPL. Wrote the manuscript: TA. Reviewed and critically revised the manuscript: HO, AA, and JPL. All authors approved the final version of the manuscript.

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