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Reliability study

Muscle thickness and echo intensity measurements of the rectus femoris muscle of healthy subjects: Intra and interrater reliability of transducer tilt during ultrasound

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This study aimed to assess the intra and interrater reliability of transducer tilt during the ultrasound (US) measurements of the muscle thickness and the echo intensity of the rectus femoris muscle (RF). Fourteen healthy male subjects (20.8 ± 0.8 years) participated in this study. The transducer tilt was measured using a digital angle gauge (°) during US. Two experimenters took two images to measure the muscle thickness (mm) and the echo intensity (a.u.: arbitrary unit). The intra and interclass correlation coefficient (ICC), standard error of measurement (SEM), and minimal detectable change (MDC) were also calculated. These measurements were immediately repeated. The ICC for the intrarater reliability for the transducer tilt, muscle thickness, and echo intensity were 0.96 (SEM: 0.9°, MDC: 2.6°), 0.99 (SEM: 0.4 mm, MDC: 0.1 mm), and 0.97 (SEM: 0.6 a.u., MDC: 1.7 a.u.), respectively. The ICC for the interrater reliability for the transducer tilt, muscle thickness, and echo intensity were 0.40 (SEM: 4.0°, MDC: 11.1°), 0.96 (SEM: 0.7 mm, MDC: 2.0 mm), and 0.95 (SEM: 0.9 a.u., MDC: 2.4 a.u.), respectively. The intrarater reliability of the transducer tilt was reliable, but the interrater reliability was questionable. Meanwhile, both the intra- and interrater reliability of the muscle thickness and the echo intensity were reliable.

1. Introduction

B-mode muscle ultrasound (US) can be useful in studying muscle wasting diseases, such as sarcopenia (Ticinesi et al., 2017). US is a relatively quick and inexpensive method for detecting muscle loss and fat infiltration by analyzing muscle thickness and echo intensity. However, ultrasound has an examiner-dependency degree higher than that of the other modes of imaging (e.g., bioelectrical impedance, dual energy X-ray absorptiometry, computed tomography, and magnetic resonance imaging), which must be recognized (Harris-Love et al., 2014).

Diligent attention to steadying the position, orientation, and inward pressure of the transducer is required during US. Relevant literature have noted a measurement error with the changes in the transducer orientation (Dupont et al., 2001; Whittaker et al., 2009). While measuring supraspinatus and deltoid muscle thickness, Dupont et al. (2001) found that a 30° variation in the transducer angle from the perpendicular to the body surface results in a 15-% error. Whittaker et al. (2009) reported that measurement errors in the transversus abdominis thickness would be observed when the US transducer rotation was >9°, the cranial/caudal tilt was >5°, and the medial/lateral tilt was >5°. Most of the studies on healthy older subjects with a low prevalence of sarcopenia were performed on the quadriceps femoris muscle (Ticinesi et al., 2017). Several studies also showed the intra and interrater reliability of measurements of muscle thickness of the anterior thigh and echo intensity of the rectus femoris muscle (RF) (Thoirs and English, 2009; Tillquist et al., 2014; Fukumoto et al., 2012; Watanabe et al., 2013). However, little is known about reliability of transducer tilt during US of the RF. The purpose of this study is to assess the intra and interrater reliability of the transducer tilt during the US measurements of the muscle thickness and the echo intensity of the RF.

2. Methods

2.1. Subjects

Fourteen healthy male volunteers were recruited through

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advertisements as physiotherapy students of the Kawasaki University of Medical Welfare. The subjects' ages, heights, and weights (mean ± standard deviation) were 20.8 ± 0.8 years, 168.6 ± 3.9 cm, and 60.5 ± 7.7 kg, respectively. None of them had any history of orthopedic or neuromuscular diseases by self-declaration. The protocol for this study was approved by the Ethics Committee of the Kawasaki University of Medical Welfare. Written informed consent was obtained from the participants, and the subjects' rights were protected.

2.2. Procedure

Two experimenters were responsible for collecting the US imaging data. The first experimenter had 6 years of experience in musculoskeletal US, while the second had 1 year of experience. B-mode (SSD-3500SX, Aloka Co. Ltd., Tokyo, Japan) with a 10 MHz transducer was used to store US. The equipment settings, including gain (49 dB), dynamic range (56 dB), and time gain compensation in the neutral position, were maintained for all the measurements. The depth setting was fixed at 5 cm. To reduce measurement error, standardization of procedures in relation to hip and knee joint positioning is important (Hacker et al., 2016). For repeated measures in the same hip and knee joint positioning, the subjects were positioned in a supine posture with a roll (100 × 600 mm) which was made of forms under their knees. The subjects were evaluated after 15 min resting and after 24 h without any vigorous physical activity. The transducer tilt was measured using a digital angle gauge (WR3651, Wixey Co. Ltd., Florida, USA) connected with a US transducer (°) (see Fig. 1). The values of more than 0° represent herein a cranial tilt from the vertical line, while those less than 0° represent a caudal tilt. Pictures of the digital angle gauge display were taken by one experimenter using a digital video camera (CX480, Sony Co. Ltd., Tokyo, Japan) positioned on a tripod 0.3 m from the participant at almost the same time as the US freezing by the same experimenter while the other experimenter decided on the transducer tilt (see Fig. 2). Because the US technician turned a face to the ultrasound monitor, he could not see a detailed angulation of the transducer tilt during measurements. The camera lens axis was orthogonal to the sagittal plane of the participants at a height that corresponded with the display. A large amount of gel was interposed between the transducer and the skin. The transducer was then transversely placed on the anterior of the right RF. The measurement level was at midway between the anterior superior iliac spine and the proximal end of the patella. A custom-built device using a pad (DSIS-HW-S5 Sanshin Enterprises Co. Ltd., Tokyo, Japan) was used to assist in keeping the transducer rotation and the measurement level. The transducer was tilted to

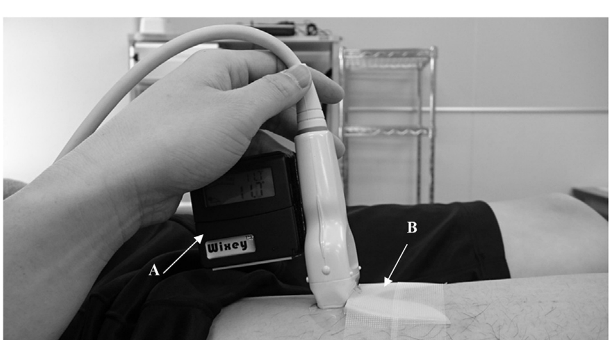

Fig. 1. Digital angle gauge.
The transducer tilt is measured using a digital angle gauge (A) connected with an ultrasound transducer. A custom-built device using a pad (B) is used to assist in keeping the transducer rotation and measurement level.

Fig. 2. Measurements of the transducer tilt and ultrasound.
Pictures of the digital angle gauge display have been taken by one experimenter (A) using a digital video camera (B) at almost the same time as the ultrasound freezing by the same experimenter while the one experimenter (C) decided on the transducer tilt.

place it in a plane, in which gave the RF a more hyper echoic appearance. Approximately 2.4 N by the transducer weight and the digital angle gauge was applied during US to unify the inward pressure condition. The experimenters stored two images of the RF to measure the muscle thickness (mm) and the echo intensity. The order of the experimenters was randomly chosen, measurements were immediately repeated.

The third experimenter, who had 2 years of experience in musculoskeletal ultrasound, performed all the muscle thickness and echo intensity measurements for blinded trial. The stored US data were converted to JPEG files and had a resolution of 640 × 480 pixels (see Fig. 3). The anteroposterior muscle thickness of the RF

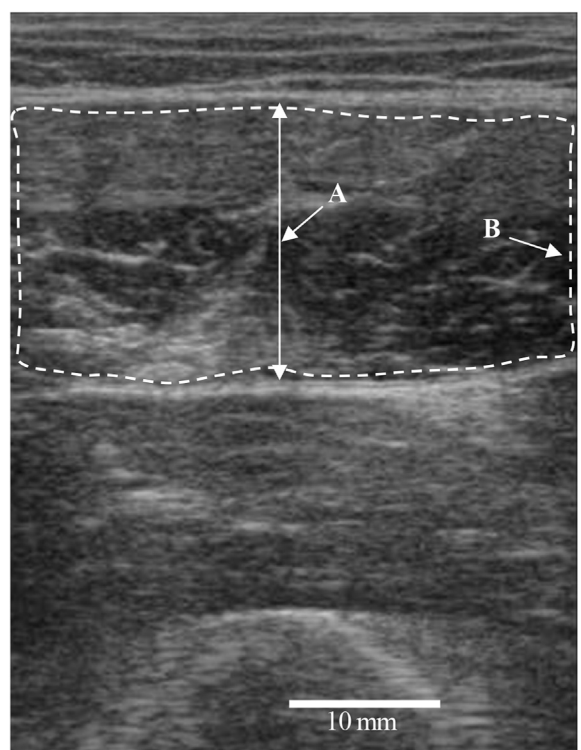

Fig. 3. Ultrasound of the rectus femoris muscle.
The anteroposterior muscle thickness was measured as the length between the superficial and deep epimysium (A). A region of interest was drawn by hand to include as much of the RF as possible without any surrounding fascia (B) and determine the echo intensity.

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