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Original Research

Intra- and inter-rater reliabilities for novel muscle thickness assessment during Co-contraction with dual-rehabilitative ultrasound imaging

Hwang-Jae Lee [a], Hyun-Geun Ha [b], Joohee Hahn [c], Seungyeop Lim [c], Wan-hee Lee [d,*]

[a] Department of Health Sciences and Technology, Samsung Advanced Institute for Health Science and Technology (SAIHST), Samsung Medical Center, Sungkyunkwan University, Samsung Medical Center Irwon-ro 81, Gangnam-gu, Seoul, 135-710, Republic of Korea
[b] Department of Physical Therapy, Namseoul University, Namseoul Univ., Seonghwan-eup, Seobuk-gu, Cheonan-si, Chungcheongnam-do, Cheonan-city, 331-707, Republic of Korea
[c] Department of Physical Therapy, The Graduate School, Sahmyook University, 815, Hwarang-ro, Nowon-gu, 01795, Seoul, Republic of Korea
[d] Department of Physical Therapy, College of Health and Welfare, Sahmyook University, 815, Hwarang-ro, Nowon-gu, 01795, Seoul, Republic of Korea

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ABSTRACT

Objectives: This study aimed to investigate the intra- and inter-rater reliabilities of dual-rehabilitative ultrasound imaging (D-RUSI) for the simultaneous measurement of the thickness of the tibialis anterior (TA) and gastrocnemius (GCM) muscles in healthy young adults.
Design: A single-group repeated-measures reliability study.
Setting: Rehabilitative ultrasound imaging analysis laboratory.
Participants: Thirty-six healthy participants (23 males; age = 26.36 ± 5.57 years).
Main outcome measures: D-RUSI was used for the simultaneous measurement of the muscle thickness of the TA and GCM at rest and during maximum voluntary contraction. Two examiners acquired data from all participants during three separate testing sessions.
Results: In the results for the intra-examiner reliability of the TA and GCM muscle thickness for two sessions, all ICC values (95% CI) were good to very good, ranging from 0.72 to 0.95 (SEM 0.01–0.05 mm, MDC 0.02–0.13 mm, respectively). In the results for the inter-examiner reliability of the TA and GCM muscle thickness for three sessions, all ICC values (95% CI) were good to very good, ranging from 0.78 to 0.97 (SEM 0.01–0.10 mm, MDC 0.02–0.15 mm, respectively).
Conclusions: These results suggest the potential usefulness of D-RUSI measurements for making management decisions related to muscle function, including muscle co-contraction.

1. Introduction

Muscle co-contraction is the simultaneous contraction of agonist and antagonist muscles cross the joint (Mari et al., 2014). It is considered to be an important motor control strategy to improve joint stability and movement accuracy (Humphrey & Reed, 1983). Actually, instantaneous co-contraction of antagonist muscles, by stiffening the joints, produces upper-extremity stability during the execution of tasks requiring positional accuracy (Bazzucchi, Sbriccoli, Marzattinocci, & Felici, 2006) and reduces lower-extremity instability during gait (Lee, Chang, Choi, Ryu, & Kim, 2017). Moreover, the increased muscle co-contraction due to various sports or musculoskeletal injuries is commonly described as a compensatory mechanism to increase join stiffness that thereby enhance stability or to avoid pain caused by damage (Nagai et al., 2011; Oliver, De Ste Croix, Lloyd, & Williams, 2014). Thus, muscle co-contraction should be a crucial factor to consider during functional motor rehabilitation in sports and musculoskeletal injuries. In particular, a recent analysis including the tibialis anterior (TA) and gastrocnemius (GCM) muscles showed that the amplitude and timing of muscle co-contraction are correlated with age and gait velocity of healthy adults (Hortobagyi et al., 2009; Lee et al., 2017). This is consistent with the observation that elderly persons exhibit greater contraction of the TA and GCM during the mid-

* Corresponding author.
E-mail addresses: goodptlee@skku.edu, goodptlee@gmail.com (H.-J. Lee), ptha@naver.com (H.-G. Ha), dakdagrr@naver.com (J. Hahn), sapns@naver.com (S. Lim), whlee@syu.ac.kr (W.-h. Lee).

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stance phase at various gait speeds, suggesting increased co-contraction across the ankle joint (Lee et al., 2017). In professional soccer player, due to excessive co-contraction of the ankle joint it has been reported that increases the risk of injury to a strong stress on the joints (Oliver et al., 2014).

The ability of the muscles to generate force depends directly on the structural properties (Blazevich & Sharp, 2005). In most studies, the complex relationship between agonist activation and antagonists underlying muscle co-contraction is commonly examined using surface electromyography (Hortobagyi et al., 2009; Lee et al., 2017; Macaluso et al., 2002). Unlike traditional diagnostic tools, such as surface electromyography, used to assess patients with muscle problems, ultrasound imaging has been used to evaluate the morphologic characteristics of muscles and related soft tissues while the patient is at rest and during contracted states such as walking and functional tasks (Linek, Saulicz, Wolny, & Mysliwiec, 2015). In the field of musculoskeletal research, ultrasound imaging has been successfully used to studying the function of various muscles (Overas, Myhrvold, Rosok, & Magnesen, 2017; Young, Stokes, & Crowe, 1984). Heckmatt et al. studied muscle atrophy and related pathological changes with ultrasound imaging was excellent indicator for muscle wasting (Heckmatt, Pier, & Dubowitz, 1988). Peculiarly, rehabilitative ultrasound imaging (RUSI) has been recommended as a noninvasive method of quantifying muscle morphology, activation, and functional movement, and has been increasingly used both in research and as a clinical tool throughout the rehabilitative process (Whittaker et al., 2007). Furthermore, RUSI has been used to assist in the application of therapeutic intervention, providing feedback to the patient and physical therapist (Teyhen, 2006). Through the measurement of muscle contraction with RUSI, muscle thickness is the most easily and readily obtained ultrasound measure of muscle size and has also shown strong relationships to maximal torque (Abe, Loenneke, & Thiebaud, 2015). However, conventional ultrasonic instruments have only one probe for image measurements, limiting the number of muscle that can be measured in real time to only one. Thus, the conventional ultrasound equipment has been impossible to use for the measurement of muscle co-contraction. To solve this problem, the dual-RUSI (D-RUSI) device, which can possibly simultaneously measure the contraction of two muscles (agonist and antagonist muscles) with its two probes, and with the two muscle measurements displayed on the screen of one personal computer, was developed at TELEMED (dual-MicrUs EXT; TELEMED, Vilnius, Lithuania) (Fig. 1).

Therefore, the main purpose of this study was to investigate the intra- and inter-rater reliabilities of D-RUSI for the simultaneous measurement of muscle thickness during co-contraction of the TA and GCM with rest and maximal dorsiflexion in healthy young adults. We hypothesized that RUSI is suitable reliable study and clinical tool for the measurement of co-contraction of ankle joint muscles.

2. Materials and methods

2.1. Participants

This study applied a single-group repeated-measures design. Two examiners acquired the images from all participants on two separate test sessions with an interval of 7 days. Thirty-six healthy young participants aged 20–36 years (23 men, 13 women) were included in the study. The participants had no history of musculoskeletal pain or disease within the last 3 months. The exclusion criteria were musculoskeletal or neuromuscular disorders in the lower extremity, pregnancy, and body mass index >30 kg/m^2.

We explained to all participants the purpose and requirements of our study and voluntarily signed the informed consent form. The study was approved by the (xx) Institutional Review Board.

2.2. Examiners

Two physical therapists participated in the reliability analysis as examiners. Examiner 1 was a physical therapist for 5 years and Examiner 2 was a physical therapist for 25 years. Before the start of this study, both examiners underwent 7 days (2 h a day for a total of 14 h). of specific training in image capturing and measurement of the thickness of the TA and medial GCM muscles, with a professional instructor who is a professor of physical therapy experienced with the specific D-RUSI protocol used in this study.

2.3. Study protocol

The two examiners acquired ultrasound images of all participants in two individual measurement sessions (1st test and 2nd test). After the 1st test was performed, the 2nd test was performed one week later. Measurement sessions were held at the same time of the day for each participant. Researcher instructed participants not to do much activity for 7 days after measuring 1st test and also checked the activity of all participants for 7 days before measuring 2nd test.

2.4. Measurement procedure

Before the first measurement, the anthropometric variables of the participants were measured by one skilled rater. The calf circumference and tibial length were measured at the thickest part of the calf muscle belly by using a tape measure. The D-RUSI device used in the study to measure the muscle thickness of the TA and GCM was an imaging unit set in real-time B-mode with a 7.5-MHz dual-linear array transducer. Presets were standardized at a frequency of 13 MHz and depth of 4 cm. Measurements of muscle thickness for the TA and GCM at rest and during maximum voluntary contraction were performed on the dominant side of each participant. Each participant was asked to perform dorsiflexion and plantarflexion of the ankle joint to the maximum extent possible. Strong verbal encouragement was given during every contraction to promote maximal effort. The muscle thickness of the TA was defined as the distance between the superficial and central aponeurosis(Maganaris & Baltzopoulos, 1999). Furthermore, the muscle thickness of the GCM was defined as the distance between the superficial and deep aponeurosis (Konig, Cassel, Intziegianni, & Mayer, 2014) (Fig. 2). These parameters have been considered to determine whether aponeuroses are parallel.

To assess the muscle thickness of the TA and GCM during ankle dorsiflexion, the participants sat on a chair with a backrest. Images of the co-activation during ankle dorsiflexion were obtained with the ankle joint in neural position (90°) and at maximal isometric contraction (Keep ankle dorsiflexion 15° for 5 s) with manual resistance by the examiner. The maximal isometric contraction values were obtained by using a digital manual muscle tester (Power Track II; JTECH Medical, Salt Lake City, UT, USA). The time point of the measurement was obtained at 5 s point in the maximal isometric contraction state. The scan image of the TA was taken at a point 20% of the superior distance from the head of the fibula to the tip of the lateral malleolus(McCreesh & Egan, 2011). The distance between the head of the fibula to the tip of the lateral malleolus was measured by using a measuring tape. Furthermore, the scan image of the GCM was taken at a point 30% of the tibial length, defined as the distance from the popliteal crease to the midpoint of the medial malleolus (Raj, Bird, & Shield, 2012) (Fig. 2). Initially, in order to standardize the position of the transducer for each