Research Report

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Intra-Rater and Inter-Rater Reliability of Muscle Length Test for Extensor Digitorum Longus

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Background A short extensor digitorum longus (EDL) is associated with limited ankle dorsiflexion, toe deformities (such as hammer toe and claw toe), and diabetic plantar ulcers. Therefore, measurement of EDL is important for the evaluation of patients with foot dysfunction.

Purpose The aim of this study was to evaluate the intra- and inter-rater reliability of the muscle length test for EDL.

Study design Repeated measures for intra- and inter-test reliability.

Methods Thirty participants were recruited. Two physical therapists evaluated EDL length based on the difference in passive ankle plantar flexion angle between relaxed and flexed toe positions. Each examiner measured it in each participant three times. The intraclass correlation coefficient was used to assess the intra- and inter-rater reliability of the muscle length test for EDL.

Results The intra- and inter-rater reliability values were 0.83 and 0.75, respectively. The standard error of measurement was 1.93° and the minimum detectable change was 5.35°.

Conclusions The muscle length test is a reliable method for measuring EDL length in clinical practice.

Key words Extensor digitorum longus; Muscle length test; Range of motion, Reliability.

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INTRODUCTION

The anterior leg muscle group includes the tibialis anterior (TA), extensor hallucis longus, and the extensor digitorum longus (EDL) muscles.[1,2] The EDL originates from the anterior fibula and passes through the dorsal digital expansion to attach to the distal phalanx of the four lesser toes. It causes ankle dorsiflexion and extension of the second through fifth toes.[1] Another pre-tibial muscle, the TA, causes ankle dorsiflexion and inversion of the subtalar joint.[2] Loss of TA action leads to dorsiflexion weakness and foot eversion during gait, resulting in foot drop and pronation. On the other hand, the EDL causes ankle dorsiflexion and eversion. Loss of EDL action leads to foot drop and forefoot varus, while EDL contracture leads to hyperextension of the metatarsophalangeal joint (MTP) during gait.[3]

Imbalance between the activity of pretibial muscles is associated with limited ankle dorsiflexion, toe deformities (such as hammer toe and claw toe), and diabetic plantar ulcers.[4,5] Jacquelin et al.[6] reported that imbalance between pretibial invertor and evertor muscles causes foot varus and reduces the range of ankle dorsiflexion. Reynard et al.[7] reported that imbalance between TA and EDL, i.e., decreased EDL activity, is important for foot varus during the swing phase of gait in stroke patients. Sharmann et al.[4] reported that insufficient ankle dorsiflexion causes overuse of the EDL and weakness of intrinsic foot muscles, and demonstrates a dorsiflexion pattern of the MTP joint during the swing phase of gait.

Hammer toe is a lesser toe deformity characterized by flexion of the proximal interphalangeal joint and dorsiflexion of the MTP joint.[8] Kwon et al.[9] reported that the toe extensor/flexor ratio was 2.3- to 3.0-fold higher, and the range of ankle dorsiflexion was lower, in hammer toe patients than in people with normal toes; the former also a significantly lower range of eversion of the subtalar joint. The authors suggested that EDL shortening due to overuse for controlling ankle movement may lead to the hammer toe deformity. In addition, Hansen[10] and Sharmann et al.[4] reported that people with hammer toe may dorsiflex the ankle due to predominant EDL contraction rather than TA contraction during daily activities.

Limited ankle dorsiflexion is common among individuals with diabetic neuropathy.[11,12] Goniometric measurements from people with hammer toe deformity have a limited range of ankle dorsiflexion.[9] Cheuy et al.[5] found that hyperextension of the MTP joint was associated with limited ankle dorsiflexion in people with diabetic neuropathy, and postulated that repeated hyperextension may lead to EDL shortening, resulting in a hyperextension deformity of that joint at rest. However, no previous study has investigated the reliability of the muscle length test for EDL, which is related to limited ankle dorsiflexion, toe deformities (such as hammer toe and claw toe), and diabetic plantar ulcer. Sharmann et al.[4] reported that insufficient dorsiflexion syndrome is characterized by EDL shortness, and that EDL length is shortened when the range of motion is smaller in ankle plantar flexion than the comfortable state in flexion of the second to fifth MTP joint. Thus, in this study, EDL length was defined as the difference in passive ankle plantar flexion angle between the relaxed and flexed positions of toes. The purpose of this study was to investigate the reliability of the muscle length test for EDL and the research hypothesis was that intra- and inter-rater reliability of the muscle length test for EDL would be high.

METHODS

Study subjects

The present study included 30 participants (8 females and 22 males) with a mean age of 22.6 years (range=20–27 years) who could dorsiflex the ankle without pain and had the normal ankle range of motion. Participants were excluded if they had sustained an ankle injury within 4 weeks prior to testing. The Institutional Review Board of Joongbu University approved the study, and written informed consent was obtained from the participants.

Experimental methods

Participants were instructed to wear shorts to allow adequate exposure from the knee joint to the foot. Three markers were attached to the fibular head, lateral malleolus, and fifth metatarsal head. The angle of active ankle dorsiflexion was measured to determine the correlation of ankle dorsiflexion and EDL length. The measurements were obtained for three trials of active ankle dorsiflexion for each participant and the average values were recorded. To measure EDL length, passive ankle plantar flexion angle was measured in the left ankle joint with the participant in a long sitting position and the foot hanging from the table edge. Two physical therapists with experience in measuring the range of ankle joint motion evaluated the EDL length by measuring the difference in passive ankle plantar flexion angle between the relaxed (Figure 1A) and flexed positions (Figure 1B) of the second and fifth MTP joints (EDL length =Toe relaxed plantar flexion angle–Toe flexed plantar flexion angle). The ankle plantar flexion angle was calculated by measuring the angle between these markers. Similar to previous studies, the ankle plantar flexion angle was measured using ImageJ software (version 1.50i; National Institutes of Health, Bethesda, MD, USA). A camera (Sony

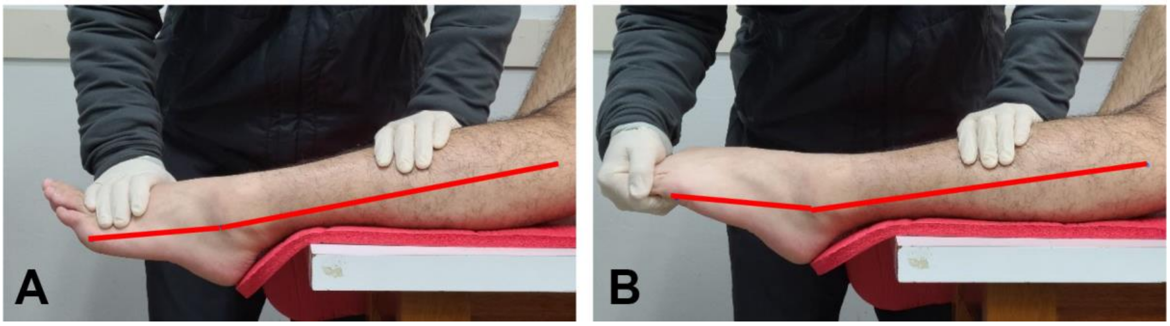

Figure 1. Passive ankle plantar flexion with relaxed (A) and flexed (B) positions of the second to fifth toes.

Electronics Inc., San Diego, CA, USA) was used to acquire and store video images. The camera was placed at a distance of 120 cm from the participants' feet and 45 cm from the ground, and was placed in a straight line with the ankle side.

The measurements were obtained in a random order by raters A and B, and the procedures were repeated by the examiners for three consecutive trials. For each rater, EDL length was measured three times in each participant to evaluate the intra-rater reliability, and the average value was used to calculate the inter-rater reliability.

Data analysis

The measurements are presented as means and standard deviations (SD). Intra- and inter-rater reliability were calculated using intraclass correlation coefficients ($ICC_{3,1}$) and 95% confidence intervals (CIs). Standard error of measurement (SEM) ($SEM=SD\times\sqrt{1-ICC}$) and the minimal detectable change (MDC; $MDC=SEM\times1.96\times\sqrt{2}$)[13] for the muscle length test of EDL were calculated. SEM reflects the absolute measurement error.[13,14] The 95% CI of MDC_{95} was used to examine clinically relevant changes in EDL length. Reliability was defined as poor (ICC<0.50), moderate (ICC =0.50–0.75), or excellent (ICC>0.75), using previously established criteria.[14] Pearson product moment correlations were used to describe the relationships between maximum ankle dorsiflexion and EDL length. Statistical analyses were performed using SPSS software (version 19.0; IBM Corp., Armonk, NY, USA).

RESULTS

For raters 1 and 2, the mean (SD) plantar flexion angles were 3.85° (4.15°) and 2.90° (3.60°), respectively. The ICCs for intra- and inter-rater reliability were .83 and .75 for the muscle length test for EDL, respectively. The SEM for the muscle length test for EDL was 1.93° and MDC was 5.35°. The data are presented in Table 1. The average active ankle dorsiflexion was 111.00° (SD=9.10°). There was a significant relationship between maximum ankle dorsiflexion and EDL length (Pearson's $r=0.54$, $p<0.05$; Figure 2).

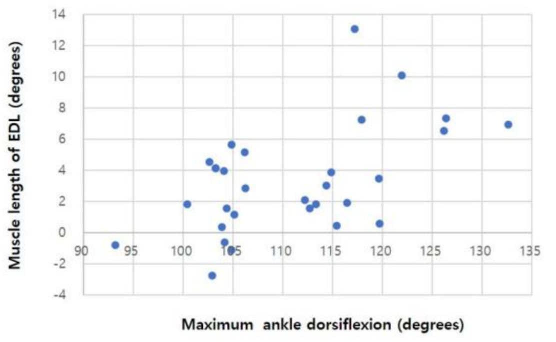

Figure 2. Scatterplot for the range of active ankle dorsiflexion and length of extensor digitorum longus.

DISCUSSION

The reliability of muscle length tests is essential to avoid measurement error, obtain accurate results, and avoid bias among studies.[15] The present study found excellent intra- and inter-rater reliability for the muscle length test for EDL (both above 0.75). Compared to other muscle length tests for lower extremity muscles, such as that for the rectus femoris, hamstring, and iliopsoas, the reliability of the muscle length test for EDL is satisfactory. The active knee extension test has shown excellent inter-rater reliability for the muscle length test for hamstrings (0.78–0.97).[16] In a previous study, the modified Thomas test showed high inter-rater reliability (ICC=0.89–0.92) for assessing rectus femoris length[17] and poor reliability (ICC, intra-rater reliability=0.52, inter-rater reliability=0.60) for assessing iliopsoas length.[18]

SEM reflects the degree of measurement error in MDC calculation, which is useful for analyzing repeated measurements.[14] MDC is the minimum degree of change in a patient's measurement that ensures that the change is not due to measurement error.[14] SEM and MDC_{95} can be used as clinical standards: for example, a change in EDL length of greater than 5.35° in patients with foot dysfunction (before and after intervention values) indicates with 95% certainty that the change is greater than the measurement error (1.93°) and thus a true change has occurred. Konor et

Table 1. Intra- and inter-rater reliability of the muscle length test for EDL

	Mean±SD	$ICC_{3,1}$ (95% CI)[a]	$ICC_{3,1}$ (95% CI)[b]	SEM	MDC_{95}
Rater A	3.85 ± 4.15	.832 (.718–.909)	.753 (.316–.789)	1.93	5.35
Rater B	2.90 ± 3.60	.833 (.720–.910)			

[a]Intra-rater reliability, [b]inter-rater reliability; EDL, extensor digitorum longus; ICC, intraclass correlation coefficient; CI, confidence interval; SEM, standard error of measurement; MDC, minimal detectable change.

al.[19] reported that the MDC for ankle dorsiflexion measured using a goniometer in the lunge position was 5.0–7.7°. In addition, Youdas et al.[20] reported an MDC of 6° for the range of active ankle dorsiflexion with knee fully extended. Unlike previous studies, we measured the plantar flexion angle in the present study; therefore, our results cannot be directly compared to those of previous studies. However, the plantar flexion angle in the present study, as reflected by the MDC, was similar to that of previous studies.

EDL causes ankle dorsiflexion and toe extension. With the ankle in a position opposing EDL functions, I measured the difference in passive ankle plantar flexion angle between the relaxed and flexed positions of the second to fifth MTP joints. In 4 of 30 participants, the difference in passive ankle plantar flexion angle between the toe positions was negative. The examiner flexed the toe and then plantar flexed the ankle joint, midtarsal joint, and first ray, following previous studies.[21,22] Therefore, the difference in EDL length was negative in participants with flexible feet. To validate the muscle length test, in further studies, passive ankle dorsiflexion should be performed after toe flexion, rather than flexion of other joints.

The main limitations of the present study are an inability to generalize the results to individuals outside of the present study's age range and to individuals with foot dysfunction. I included healthy individuals aged 20–32 years. Although there was a significant relationship between maximum ankle dorsiflexion and EDL length, I did not compare the EDL length between individuals with limited and normal ranges of ankle dorsiflexion. Sharmann et al.[4] addressed reported that insufficient dorsiflexion syndrome is characterized by EDL shortness. Therefore, further research is needed, which should include participants with a wide age rage and limited ankle dorsiflexion.

CONCLUSION

The present study recommends a reliable EDL length test based on the difference in passive ankle plantar flexion angle between relaxed and flexed toe positions in clinical practice.

Key Points

Question How reliable is the muscle length test for extensor digitorum longus?

Findings The intra- and inter-rater reliability were excellent.

Meaning The test showed excellent inter- and intra-rater reliability for the evaluation of foot dysfunction.

Article information

Conflict of Interest Disclosures: No potential conflict of interest relevant to this article was reported.

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Ethic Approval: This study was approved by the Institutional Review Board (IRB) of Joongbu University.

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