

Non–Weight-Bearing and Weight-Bearing Ultrasonography of Select Foot Muscles in Young, Asymptomatic Participants: A Descriptive and Reliability Study

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ABSTRACT

Objective: The primary aim of this study was to determine the reliability of diagnostic ultrasound imaging for select intrinsic foot muscles using both non–weight-bearing and weight-bearing postures. Our secondary aim was to describe the change in muscle cross-sectional area (CSA) and dorsoplantar thickness when bearing weight.

Methods: An ultrasound examination was performed with a linear ultrasound transducer operating between 9 and 12 MHz. Long-axis and short-axis ultrasound images of the abductor hallucis, flexor digitorum brevis, and quadratus plantae were obtained in both the non–weight-bearing and weight-bearing postures. Two examiners independently collected ultrasound images to allow for interexaminer and intraexaminer reliability calculation. The change in muscle CSA and dorsoplantar thickness when bearing weight was also studied.

Results: There were 26 participants (17 female) with a mean age of 25.5 ± 3.8 years and a mean body mass index of 28.0 ± 7.8 kg/m². Inter-examiner reliability was excellent when measuring the muscles in short axis (intraclass correlation coefficient >0.75) and fair to good in long axis (intraclass correlation coefficient >0.4). Intraexaminer reliability was excellent for the abductor hallucis and flexor digitorum brevis and ranged from fair to good to excellent for the quadratus plantae. Bearing weight did not reduce interexaminer or intraexaminer reliability. All muscles exhibited a significant increase in CSA when bearing weight.

Conclusions: This is the first report to describe weight-bearing diagnostic ultrasound of the intrinsic foot muscles. Ultrasound imaging is reliable when imaging these muscles bearing weight. Furthermore, muscle CSA increases in the weight-bearing posture. (J Manipulative Physiol Ther 2016;39:655-661)

Key Indexing Terms: *Ultrasonography; Foot; Muscle; Skeletal; Weight Bearing*

INTRODUCTION

Understanding of the intrinsic foot muscles in human locomotion and postural control, especially the abductor hallucis (AH), flexor digitorum brevis (FDB), and quadratus plantae (QP), has increased as of late.¹⁻⁴ The size of the AH muscle has been reported to be significantly reduced in patients with hallux valgus deformity and pes planus.⁵⁻⁷ Intrinsic foot muscle strength during a toe-curl exercise correlates well with the muscle cross-sectional area (CSA) measured using magnetic resonance imaging (MRI), and thus, CSA may reflect

foot muscle force generation capability.⁸ Although electromyography has principally been used to study intrinsic foot muscle function,²⁻⁴ diagnostic ultrasonography (US) can image the AH, FDB, and QP muscles in vivo in both the long and short axes, providing muscle dorsoplantar thickness and CSA, respectively.⁹⁻¹¹ Considering the ease, safety, and dynamic capability of diagnostic US imaging, future investigations will continue to use US to study intrinsic foot muscle morphology in a variety of foot deformities and pain syndromes.

Although the reliability of US in imaging the AH muscle has been established,⁹⁻¹² limited reports describe the reliability of US in imaging the FDB and QP muscles.^{10,11} Additionally, the sample sizes of the latter studies were small (10 participants in each study). Furthermore, no study has examined the reliability of US in measuring intrinsic foot muscles in a weight-bearing posture. This seems wanting as the intrinsic foot muscles function during weight-bearing activities, and as such, it would be preferable to study them in this state. Also, knowledge of muscle size while bearing weight in asymptomatic participants will be useful if future investigations of

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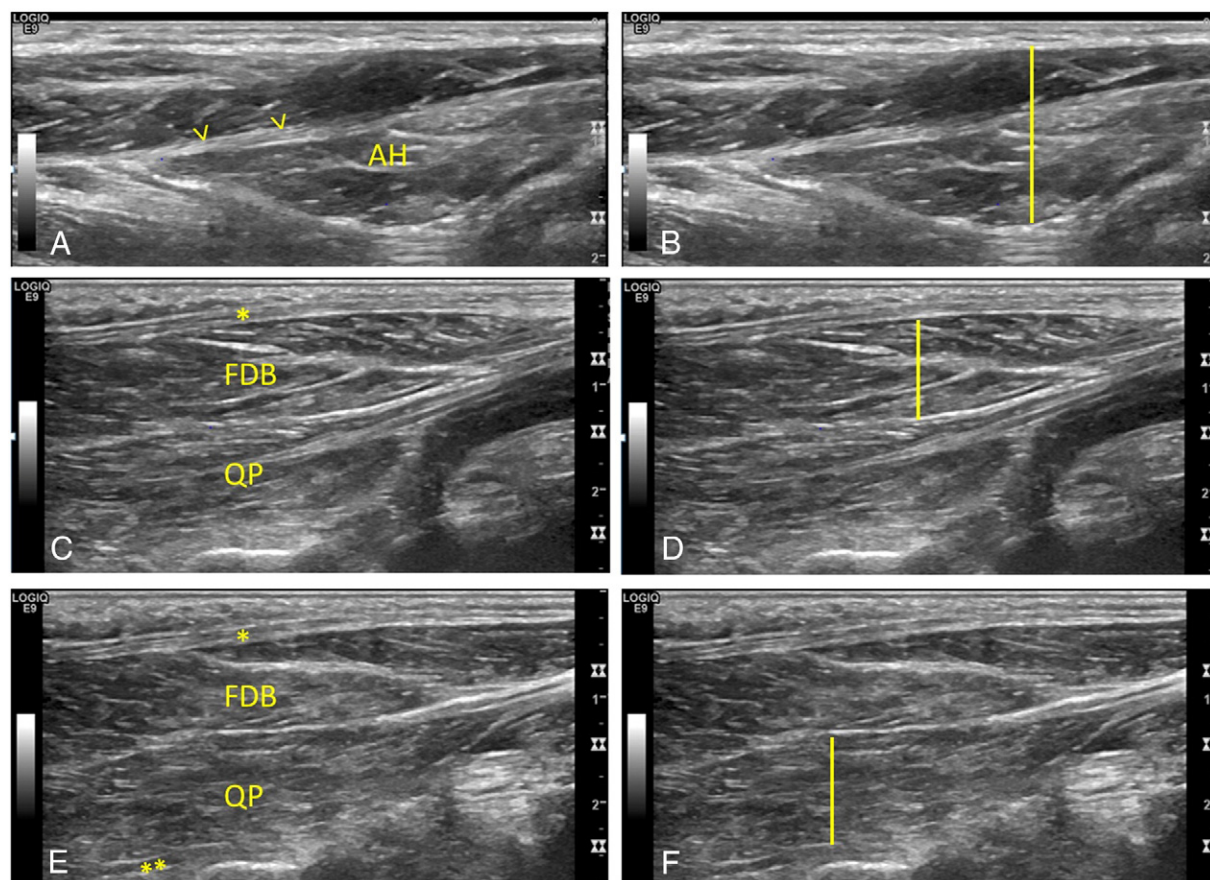


Fig 1. Long-axis images of the abductor hallucis (AH), flexor digitorum brevis (FDB), and quadratus plantae (QP) muscles. A and B, Largest dorsoplantar thickness of the AH muscle (vertical line in B). Note the prominent central tendon within the AH muscle (arrowheads in A). C and D, Largest dorsoplantar thickness of the FDB muscle (vertical line in D). Appreciate also the superficial plantar fascia (*) in C and E) and deep QP muscle in relation to the FDB. E and F, Largest dorsoplantar thickness of the QP muscle (vertical line in F). The hypoechoic long plantar ligament (**) in E) demarcates the inferior border of the QP muscle.

foot pathology are conducted in the weight-bearing posture. Thus, the principal aim of our study was to determine the interexaminer and intraexaminer reliability of long-axis and short-axis US imaging of the AH, FDB, and QP muscles in both non-weight-bearing and weight-bearing postures. Our secondary aim was to describe the changes in dorsoplantar thickness and CSA of the AH, FDB, and QP muscles when bearing weight compared with when not bearing weight in participants without foot or ankle pain.

METHODS

Participants were recruited through university advertisements and provided informed consent prior to study participation. This study was approved by the Logan University Institutional Review Board and was given the control number RD0723140494. Participants between the ages of 20 and 65 years were included. Foot or ankle pain in the preceding 6 months, history of foot or ankle surgery, or a

diagnosis of a neuromuscular disease (ie, diabetes mellitus) excluded individuals from participation. Height and weight were taken to allow for body mass index (BMI) calculation using the formula: weight (kg)/height (m).^{2,13} Separate examiners with 2 (rater 1) and 4 (rater 2) years of US experience, respectively, performed independent US examinations. We used a GE Logiq E9 (GE Healthcare, Wauwatosa, WI) US system with a linear transducer (ML6-15) operating between 9 and 12 MHz for the AH muscle and at 9 MHz for the FDB and QP muscles. To optimize US images, the examiner made depth, focal position, and contrast adjustments permitting high-resolution images of the muscle of interest, including its hyperechoic epimysial border. Probe compression was kept at a minimum to ensure there was no distortion of muscle size. Each US examination began with the participant supine and the foot extending off the examination table to image the AH muscle. The participant's right or left foot was selected to be imaged at random unless he or she reported remote (ie, >6 months) foot or ankle pain. In this instance, the contralateral foot was imaged. The US transducer

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