

VALIDATION OF A FREEHAND 3D ULTRASOUND SYSTEM FOR MORPHOLOGICAL MEASURES OF THE MEDIAL GASTROCNEMIUS.

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INTRODUCTION

Muscle volume provides an indication of the entire contractile material of a muscle and predicts muscle force generating capabilities. Active and passive muscle forces are also intricately related to muscle length. Therefore, the evaluation of muscle volume and muscle length has become necessary in studies that investigate muscle morphological and mechanical changes occurring with age, function, pathology, surgery and training.

Freehand 3D ultrasound (3DUS) involves combining 2D ultrasound scanning and 3D motion analysis to provide a direct in vivo measurement of tissue structure. Freehand 3DUS systems have been used in only a small number of studies to measure muscle morphological factors of in vivo and cadaveric human muscles. Despite this continued use in humans, no validation or reliability study has been performed in vivo. In addition, the accuracy and repeatability of large muscle volume and muscle belly length measures, requiring multiple ultrasound sweeps, in different joint positions has not been assessed.

The purpose of this study was therefore to assess the validity and the reliability of the measurement of medial gastrocnemius muscle volume and muscle belly length in vivo using multiple sweeps freehand 3DUS system compared to MRI at a range of ankle joint angles.

METHODS

The medial gastrocnemius of ten subjects was scanned at three ankle joint angles (15°, 0° and -15° dorsiflexion) three times using the freehand 3DUS and once on the following day using MRI. All freehand 3DUS and MRI images were segmented, volumes rendered and volumes and muscle belly lengths measured.

RESULTS AND DISCUSSION

Muscle volumes assessed in the study were in the range 173 – 451 mL and the muscle belly lengths were in the range of 215 – 295 mm. The freehand 3DUS overestimated muscle volume by 1.9 ± 9.1 mL, $1.1 \pm 3.8\%$ difference and underestimated muscle belly length by 3.0 ± 5.4 mm, $1.3 \pm 2.2\%$ difference. The ICCs (3,1) for repeated freehand 3DUS system measures of muscle volume and muscle belly length were greater than 0.99 and 0.98 respectively. The ICCs (3,1) for the segmentation process reliability for the freehand 3DUS system and MRI for muscle volume were both greater than 0.99 and muscle belly length were 0.97 and 0.99, respectively.

Freehand 3DUS is a valid and reliable method for the measurement of relatively large muscle volume and muscle belly length in vivo using multiple sweeps freehand 3DUS imaging over a large range of ankle joint angles. Errors in length and volume measurement of less than 2% in relatively large muscles can be considered negligible when using morphology measures to make estimates of muscle force or a muscles length range. Repeated scans using the freehand 3DUS at each ankle angle and repeated post-scanning segmentation indicated high repeatability of the system. The freehand 3DUS could be used as an alternative to MRI for measuring these in vivo muscle morphological characteristics. In addition, ultrasound technology enables the measurement of anatomical cross sectional area, muscle-tendon length, fibre length and pennation angle during the brief time for data collection. This allows the determination of the physiological cross sectional area (PCSA) and estimation of the force generating capacity of individual muscles within the setting of a biomechanics laboratory.