# The Application of Ultrasound Imaging in the Musculoskeletal Modeling Process

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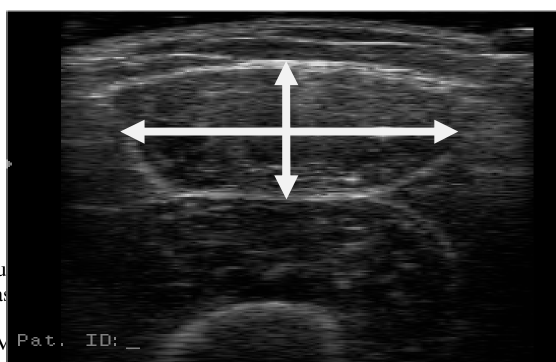
## Introduction

The size of muscles vary, and this has been shown to influence the strength of a muscle. Hill muscle models are commonly used in musculoskeletal modeling to predict muscle forces [1]. The majority of muscle models are derived from Hill's original equations and use the physiological cross-sectional area (PCSA). However there are no low-cost, fast methods of determining the PCSA of a muscle for a living subject. Currently magnetic resonance imaging (MRI) has been used to measure patient specific anthropometric details of muscle and tendon size. There is evidence to suggest that generic scaled models are inaccurate in the anthropometric detail and this in turn has a direct effect on muscle force outputs and therefore joint kinetics [2].

In recent years ultrasound imaging technology has developed to a stage where it has found widespread application and can offer a safe, objective and relatively inexpensive means of examining the musculoskeletal system [3]. Ultrasonography has been applied to study in vivo changes in muscle architecture and tendon/aponeurosis mechanical properties, both during static and dynamic conditions [4]. In order to create patient specific anthropometric muscle scaling factors for musculoskeletal modeling, there is a need to find correlations between muscle size and force output. The current research aims to determine the relationship between percentage maximal voluntary contraction (MVC) and changes in linear and cross-sectional area (CSA) of rectus femoris (RF) muscle.

## Methods

Ten healthy male participants were imaged using a Pie Medical 'Aquila' ultrasound scanner (ESAOTE S.p.A. Genova, Italy) with a 6.0 MHz linear transducer (60mm footprint). RF was imaged 2/3 distally from the anterior superior iliac spine to the superior aspect of the patella in the sagittal plane. MVC was assessed with the knee at 90° flexion using a Biodex system II Isokinetic dynamometer (Biodex Medical Systems, Shirley, New York) giving torque values for MVC and percentages of MVC. Two images were taken at rest, followed by two images at MVC. Two repeated tests were then taken in random order for 10%, 20%, 30%, 50% and 75% MVC, with 1 minute rests between tests.




Figu... near meas...

M... h of RF ... rior borders. Width was measured at the mid-point of depth, between the two lateral borders, and CSA was measured by tracing round the circumference of the inside of the fascia (Figure 1). The mean of two measures for each dimension was taken for each scan and then the mean of the 2 images taken for each condition was used in the analysis.

In a reliability study of 2 subjects, between-day reliability of repeated scans at rest was good to moderate, with intra-class correlation coefficients of 0.93, 0.60, and 0.57 for depth, width and CSA respectively For the main study, linear regression analysis was used to calculate coefficients between % MVC change and % dimension change with 95% confidence intervals.

## Results

These preliminary results from 10 participants show width measurements have the strongest correlation to MVC production (r=0.94) with 80% of data points lying within the 95% confidence intervals (Figure 2).

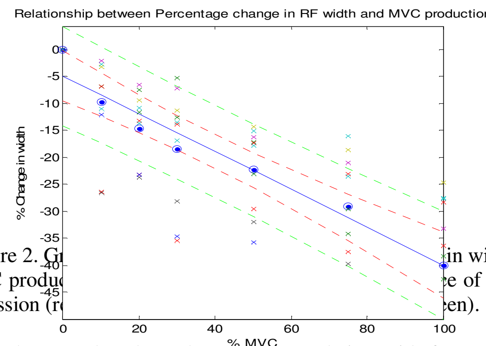



Figure 2. G... in width and % MVC produ... e of interval of regression (r... en).

CSA changes also showed a strong correlation with force (r=0.99) but with 39% of the results being outliers from the 95% confidence intervals. Depth measurements showed a poor correlation with force (r=-0.04), and a wide spread of values across the % MVC tests.

## Discussion

Preliminary results show that changes in width and CSA measures of RF show a correlation with % MVC production. This result is further supported by previous work from [6], who found a relationship at low forces. Ultrasound imaging is currently being validating across diagnostic and rehabilitation practice, this study highlights a further use of this modality for determining muscle activity and patient specific anthropometrics for musculoskeletal models. There are limitations to ultrasound imaging in terms of scan area/depth and inter-operator reliability, but with the speed/ease of use, there is a strong case for its use in determining both muscle size and muscle activity measures. These results show a clear relationship between force production and linear/CSA measurements of muscle belly, this in turn can then be used in subject specific musculoskeletal models to scale strength and muscle PCSA.

## Acknowledgements

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## References

1. Zajac, F.E., *Understanding muscle coordination of the human leg with dynamical simulations.* J Biomech, 2002. **35**(8): p. 1011-1018.
2. Scheys, L., et al., *Calculated moment-arm and muscle-tendon lengths during gait differ substantially using MR based versus rescaled generic lower-limb musculoskeletal models.* Gait & Posture. In Press, C. Proof
3. Whittaker, V.J., et al., *Rehabilitative Ultrasound Imaging: Understanding the Technology and Its Applications.* J Orthop Sports Phys Ther, 2007. **37**(8): p. 434-449.
4. Narici, M., *Human skeletal muscle architecture studied in vivo by non-invasive imaging techniques: functional significance and applications.* J Electromyogr Kinesiol, 1999. **9**(2): p. 97-103.
5. Abramoff, M., *"Image Processing with ImageJ".* Biophotonics International, 2004. **11**(7): p. 36-42.
6. Chi-Fishman, G., et al., *Ultrasound imaging distinguishes between normal and weak muscle.* Arch Phys Med Rehabil, 2004. **85**(6): p. 980-986.