Pretorius A, Keating JL. Validity of real time ultrasound for measuring skeletal muscle size. *Physical Therapy Reviews* 13:415-426, 2008.
Objectives: To identify what is known about the validity of real time ultrasound (RTUS) measurements of skeletal muscle size and to summarise populations and conditions that have been assessed with RTUS. Methods: Seven databases were searched for potential study inclusion. All identified studies were assessed with inclusion criteria and a quality assessment scale. Each study reported muscle size measurements with RTUS and a reference standard (either MRI or CT). Muscle sizes were measured as a muscle thickness (linear dimension), a muscle area (cross sectional area or CSA) or as a muscle volume (anatomical cross sectional area or ACSA). Results: Thirteen studies were identified for inclusion in this systematic review. Measures of correlation coefficient, coefficient of determination and mean effect size changes were determined. All of the studies in the review came to the same conclusion – that RTUS is a valid alternative to objectively measure muscle size when compared to gold standards such as MRI or CT. Discussion: All the studies in the review came to the conclusion that RTUS can provide valid measurements of skeletal muscle. The populations represented in this review were adequately varied to warrant generalisation of the results.
doi:10.1179/174328808X356447

O'Sullivan C, Meaney J, Boyle G, Gormley J, Stokes M. The validity of rehabilitative ultrasound imaging for measurement of trapezius muscle thickness. *Manual Therapy*. 14:572-578, 2009.
The purpose of the study was to establish the validity of rehabilitative Ultrasound Imaging (RUSI) against Magnetic Resonance Imaging (MRI) for measuring trapezius muscle thickness. Participants were asymptomatic subjects recruited from Trinity College Dublin and associated teaching hospitals. Four MRI axial slices were made through each of the C6, T1, T5 and T8 spinous processes, with the subject supine. RUSI was performed immediately after MRI at the same vertebral levels, with the subject prone. Linear measurements of trapezius muscle thickness were made off-line on both the MRI and Ultrasound scans, in three regions: lower, middle and upper trapezius. Bland and Altman limits of agreement and Pearson's correlation coefficient were used to analyse the relationship between thickness measures taken from MRI and RUSI. Eighteen subjects (9 women) participated, (age-range 21-42 years). Results demonstrated good agreement between MRI and RUSI measurements of the lower trapezius muscle at T8 (r=0.77) and moderate agreement at T5, (r=0.62). Results were poor for the middle (T1) and upper (C6) trapezius muscles, (r=-0.22 to 0.52) but may be explained by differences in both positioning and imaging planes between the 2 modalities. It was concluded that RUSI is a valid method of measuring lower trapezius muscle thickness.
doi: 10.1016/j.math.2008.12.005 http://www.ncbi.nlm.nih.gov/pubmed/19264532

Mendis MD, Wilson SJ, Stanton W, Hides JA. Validity of real-time ultrasound imaging to measure anterior hip muscle size: a comparison with magnetic resonance imaging. *Journal of Orthopedic and Sports Physical Therapy* 40:577-581, 2010.
STUDY DESIGN: Clinical measurement, criterion standard. OBJECTIVES: To investigate the validity of real-time ultrasound imaging (USI) to measure individual anterior hip muscle cross-sectional area. BACKGROUND : The hip flexor muscles are important for hip joint function and

could be affected by joint pathology or injury. Objectively documenting individual anterior hip muscle size can be useful in identifying muscle size asymmetry and monitoring treatment efficacy for patients with hip problems. USI offers a novel method of measuring individual muscle size in the clinic, but its validity in measuring the anterior hip muscles has not been investigated. METHODS: Nine healthy participants (5 males, 4 females) underwent imaging of their iliopsoas, sartorius, and rectus femoris muscles with USI and magnetic resonance imaging. Bilateral muscle cross-sectional areas were measured on images from both modalities. RESULTS: There was no significant difference (*P*>.05) in mean cross-sectional area measurements from USI and magnetic resonance imaging for each muscle. Agreement between measurements was high for the iliopsoas (left: intraclass correlation coefficient [ICC3,1] = 0.86; 95% confidence interval [CI]: 0.51, 0.97; right: ICC3,1 = 0.88; 95% CI: 0.57, 0.97), sartorius (left: ICC3,1 = 0.82; 95% CI: 0.41, 0.96; right: ICC3,1 = 0.81; 95% CI: 0.39, 0.95), and rectus femoris (left: ICC3,1 = 0.85; 95% CI: 0.49, 0.96; right: ICC3,1 = 0.89; 95% CI: 0.61, 0.97). Reliability of measuring each muscle with USI was high between 2 trials (ICCs3,1 = 0.84 to 0.94). CONCLUSION : USI is a valid measure of iliopsoas, sartorius, and rectus femoris muscle size in healthy people, as long as a strict measurement protocol is followed.
doi:10.2519/jospt.2010.3286 http://www.ncbi.nlm.nih.gov/pubmed/20479536

Worsley PR, Kitsell F, Samuel D, Stokes M. Validity of measuring distal vastus medialis muscle using rehabilitative ultrasound imaging versus magneticresonance imaging. *Manual Therapy* 19:259-263, 2014.
Objective quantification of muscle size can aid clinical assessment when treating musculoskeletal conditions. To date the gold standard ofmeasuring muscle morphology is magnetic resonance imaging (MRI). However, there's a growing body of evidence validating rehabilitative ultrasoundimaging (RUSI) against MRI. OBJECTIVE: This study aimed to validate RUSI against MRI for the linear measurements of the distal fibres of vastus medialis muscle in the thigh. Twelve healthy male participants were recruited from a local university population. The distal portion of their right vastus medialis was imaged with the participant in long-sitting, using MRI and RUSI whilst the leg was in extension and neutral hip rotation. Cross sectional area (CSA) and three linear measures were taken from the MRI and these were compared with the same linear measures from RUSI. Statistical analysis included comparison of MRI and RUSI measures using the paired t-test and intra-class correlation coefficients (ICC 3,1). Mean differences between the linear measures taken from the MRI and RUSI were -0.5 mm to 2.9 mm (95% confidence intervals -0.6-8.3 mm), which were not statistically different ($p > 0.05$) and were highly correlated (ICCs 3,1 0.84-0.94). Correlations between the three linear measurements and muscle CSA ranged from $r = 0.23$ to 0.87, the greatest being muscle thickness. Multiplying the linear measures did not improve the correlation of 0.87 found for muscle thickness. Linear measures of vastus medialis depth made using RUSI were shown to be as valid as using MRI. Muscle thickness measures using RUSI could be used within an objective assessment of this muscle.
doi: 10.1016/j.math.2014.02.002. http://www.ncbi.nlm.nih.gov/pubmed/24582328

Belavý DL, Armbrecht G, Felsenberg D. Real-time ultrasound measures of lumbar erector spinae and multifidus: reliability and comparison to magnetic resonance imaging. *Physiological Measurement*. 36:2285-9922, 2015.

In this work we examine the reliability and validity (in comparison to magnetic resonance imaging; MRI) of real-time ultrasound measures of lumbar erector spinae thickness. We also consider the between-day reliability of the lumbar multifidus muscle area as measured via ultrasound. 23 male subjects aged 21-45 years were measured three times over the course of nine days by one operator. The first (L1) through to the fifth (L5) lumbar vertebral levels were measured on the left and right sides. MRI was performed on the same day as first ultrasound scanning. For between-day intra-rater reliability, intra-class correlation co-efficients (ICCs), standard error of the measurement, minimal detectable difference and co-efficients of variation (CVs) were calculated along with their 95% confidence intervals and Bland-Altman analysis was performed. On Bland-Altman analysis, erector spinae thickness and multifidus area ultrasound measures 'agreed' with equivalent MR measures, though the correlation between MR and ultrasound measures was typically poor to moderate. For both ultrasound measures, the ICCs ranged from 'moderate' to 'excellent' at individual vertebral levels, although multifidus area (CV ranged from 8 to 15%) was less reliable than erector spinae thickness (CV ranged from 6 to 10%). 'Agreement' on Bland-Altmann analysis was present between days for all ultrasound measures. Averaging between sides and between vertebral levels improved reliability. Average erector spinae thickness showed a CV of 5.5% (ICC 0.77) and average multifidus area 6.2% (ICC 0.80).

doi: 10.1088/0967-3334/36/11/2285 http://www.ncbi.nlm.nih.gov/pubmed/26450474