Automated Fat and Muscle Quantification in the Thigh and Calf

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Target Audience: Researchers and clinicians interested in tracking and measuring body composition in the extremities.

Purpose: Measurements of muscle volume and fat distribution in the extremities are important for quantifying atrophy and fatty infiltration progression or disease state in conditions such as Duchenne Muscular Dystrophy (DMD), Spina Bifida, Sarcopenia, and Cachexia. Loss of muscle bulk and strength along with fatty infiltration of the muscle has been linked to reduced mobility, disability, decreased quality of life and mortality[1,2]. Water-fat separated MRI provides simultaneous 3D acquisitions of muscle and fat tissues allowing for segmentation and measurement of Subcutaneous Adipose Tissue (SAT), Inter-Muscular Adipose Tissue (IMAT), and muscle from a single acquisition. Post-processing of large volumetric data sets still remains a user-intensive process and requires automation to be feasible for large scale studies. The purpose of this work was to extend previously validated segmentation software used in the abdomen[3] for use with the lower extremities and validate it against manual segmentation.

Methods: Following REB approval and obtaining informed consent, *in vivo* thigh and calf MRI data were obtained retrospectively from 12 subjects from 3 study cohorts which represent a wide range of possible muscle atrophy and fat distributions. Study cohorts included subjects with Dunnigan Type Familial Partial Lipodystrophy (FPLD2, n=4) representing patients with very little subcutaneous adipose, adolescents diagnosed with DMD or Spina Bifida (n = 4) representing patients with high fatty infiltration to the muscle, and healthy adults (n=4). As the study used retrospective data, various hardware and sequence parameters were used. All data were collected using IDEAL-IQ on GE 3.0 T MR750 (GE Healthcare, Waukesha, WI), or mDixon on a Phillips 3.0 T Acheiva (Best, The Netherlands) using 3- or 6 echoes and a multi-coil phased array.

The previously validated automated method uses fat fraction values to identify adipose and lean muscle tissue, and recognition of the external 3D muscle surface of the water images in polar coordinates to segment SAT from internal adipose tissue. This algorithm was extended with common image processing methods (connectivity, convex-hull, and flood fill operations) to remove bone marrow and separate limbs when both were acquired in the field of view. Volumetric automated segmentation was performed, and compared with manual segmentation for single slices located at the mid-thigh and mid-calf using a previously validated method for water-fat imaging[4].

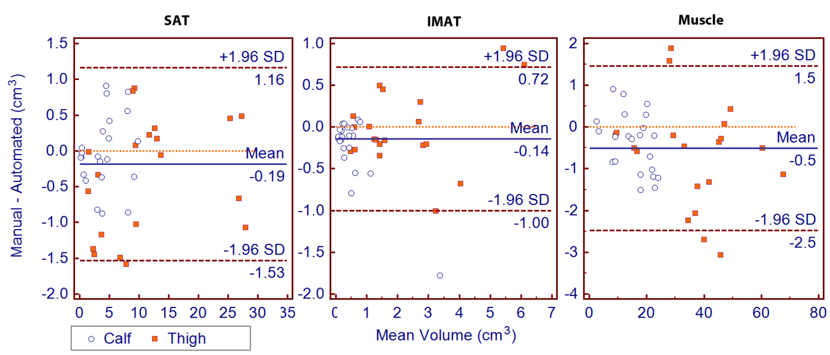

Figure 1 – Bland Altman plots showing agreement between manual and automated segmentation for Subcutaneous Adipose Tissue (SAT), Inter-Muscular Adipose Tissue (IMAT), and Muscle

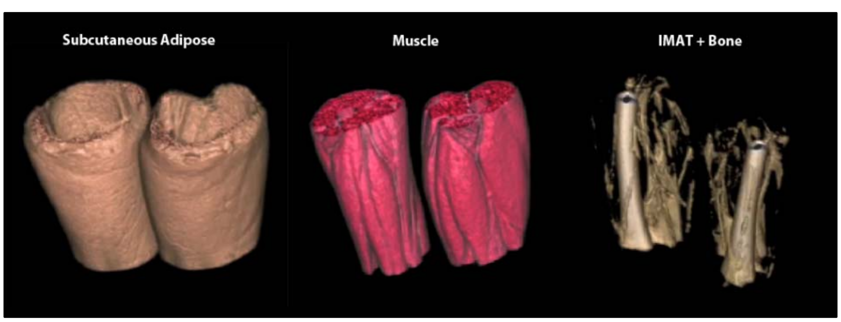

Figure 2 - 3D volumetric tissue segmentation. (A) SAT (B) Muscle, (C) IMAT + Bone. The bone was removed from the segmentation but included in the IMAT visualization for anatomical reference.

Results: The absolute mean volume difference between manual and automated segmentation methods was 0.30 ± 0.35 cm^3 for SAT, 0.55 ± 0.45 cm^3 for IMAT, and 0.84 ± 0.74 cm^3 for muscle. Graphical comparison of the agreement between methods can be seen via Bland-Altman plot (Figure 1).

Discussion: Excellent agreement was found for SAT, IMAT, and muscle tissue with no substantial bias. Automated segmentation was approximately 80x faster than manual segmentation and was successful in all cases. However, the automated algorithm can fail with severe fatty infiltration (muscle fat fraction > 40%) as muscle tissue can no longer be automatically differentiated from SAT, or IMAT. This is due to the automated tool defining fat fractions greater than 40% as adipose tissue belonging to the SAT or IMAT compartments.

Conclusions: We have demonstrated that extension of the previously validated algorithm is suitable for high accuracy measurement of muscle and fat in the lower extremities.

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