Assessment of changes in regional distribution of skeletal muscle adipose tissue in type 2 diabetes using quantitative IDEAL gradient echo imaging

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Introduction: Type 2 diabetes has been recently associated with alterations in regional distribution of adipose tissue in the lower extremities, including changes in intermuscular adipose tissue (IMAT) and subcutaneous adipose tissue (SAT) [1, 2]. Segmentation of T_1-weighted images has been traditionally used to quantify IMAT and SAT. However, fat measurements based on T_1-weighted imaging require effective segmentation procedures and are not able to assess lipid concentrations in localized muscular regions [3,4]. These limitations of T_1-weighted imaging can considerably falsify the assessment of regional variation of fat among different compartments. Fat selective imaging [3,4] and high spatial resolution spectroscopic imaging [5] have been previously proposed as ways to overcome these limitations. However, fat selective imaging is in general sensitive to B_o inhomogeneities and spectroscopic imaging suffers from prolonged acquisition times. Chemical shift-based water/fat separation techniques, like the iterative decomposition of water and fat with echo asymmetry and least-squares estimation (IDEAL) [6], have been recently developed for quantitative fat measurements in the liver [7,8] and implemented for quantifying muscular fat [9,10]. The purpose of the present study is to assess the changes in regional distribution of adipose tissue in type 2 diabetes based on the fat fraction maps of quantitative IDEAL.

Methods: 46 post-menopausal women (27 controls with mean age 60.6±5.0 years and 19 diabetics with mean age 61.4±5.5 years) were recruited for this study. The right middle-calf muscle region of the subjects was scanned on a 3.0 T whole-body GE scanner using an 8-channel low extremity coil. A set of axial 2D fast-spin echo T_2-weighted images were acquired for segmentation purposes and an investigational version of 6-point IDEAL in a 3D multi-shot multi-echo flyback SPGR sequence was used to measure fat content (TR/TE/ΔTE=12/1.4/0.7 ms, flip angle=5°, ETL=2, bandwidth=83.33 kHz, 180x180 matrix size, FOV=18 cm, 30 slices with 4 mm thickness). The computation of fat fraction was based on the IDEAL algorithm with multi-peak spectral modeling of fat and T_2* correction [7], using the precalibrated fat spectrum as in [11] and the magnitude discrimination approach to remove noise-induced bias at low fat fractions [12]. The in-phase images (IDEAL separated water+fat) were manually segmented to define the SAT and total muscle regions (excluding tibia and fibula). The T_2-weighted images were manually segmented to define 6 compartments within the muscular region: anterior compartment (AC), deep posterior compartment (DP), lateral gastrocnemius (LG), medial gastrocnemius (MG), peroneus (PER) and soleus (SOL). The adipose tissue volume was computed in all compartments based on the quantitative fat fraction map. The total adipose tissue (TAT) compartment was defined as the sum of SAT and IMAT compartments. The IMAT compartment was defined as the sum of intramuscular fat (intraMF, containing all six muscular region compartments in Fig. 1c), and intermuscular fat (interMF, containing fat lying only between the different muscle compartments in Fig. 1d). Two sample Student's t-tests were used to perform statistical comparisons between the two groups.

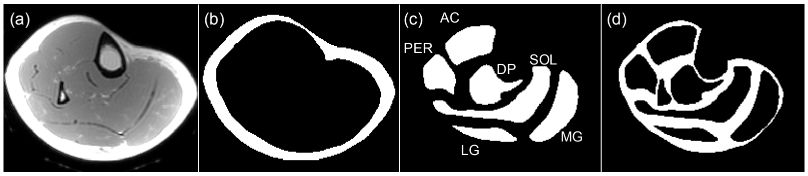

Fig. 1: Segmentation of muscle compartments: (a) typical in phase image, (b) subcutaneous adipose tissue (SAT) mask, (c) masks of 6 muscular compartments, and (d) intermuscular tissue mask. Intramuscular fat (intraMF) represents fat within the mask of (c) and the intermuscular fat (interMF) represents fat within the mask of (d).

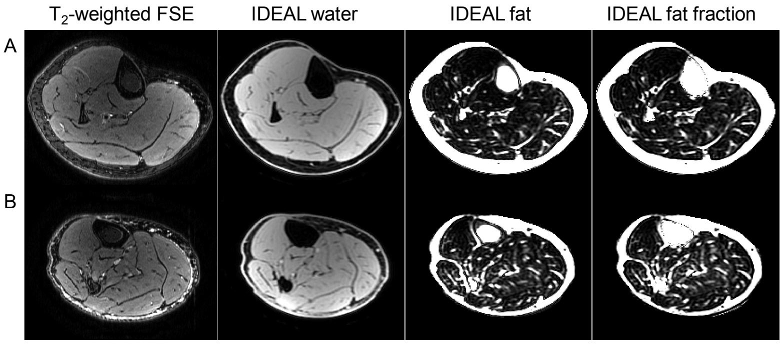

Fig. 2: Comparison of water/fat separation results for a control subject A (age 63, BMI 26.8) and a diabetic subject B (age 63, BMI 28.3): T_2-weighted FSE, water, fat and fat fraction IDEAL images.

Results: The adipose tissue distribution of a control subject is compared with the adipose tissue distribution of an age- and BMI-matched diabetic subject in Fig. 2. The diabetic subject is characterized by higher contribution of IMAT to TAT and a lower contribution of SAT to TAT in comparison with the control subject. The group results also show that the relative composition of TAT changes between diabetics and controls with a significantly higher fraction of TAT within IMAT for diabetics than controls (p=0.002, Fig. 3a). The relative composition of IMAT also changes between diabetics and controls with a significantly higher fat fraction of IMAT within intraMF for diabetics than controls (p=0.026, Fig.3b). Furthermore, Fig. 3c shows the changes in the composition of IMAT within the six muscle compartments under study between diabetics and controls.

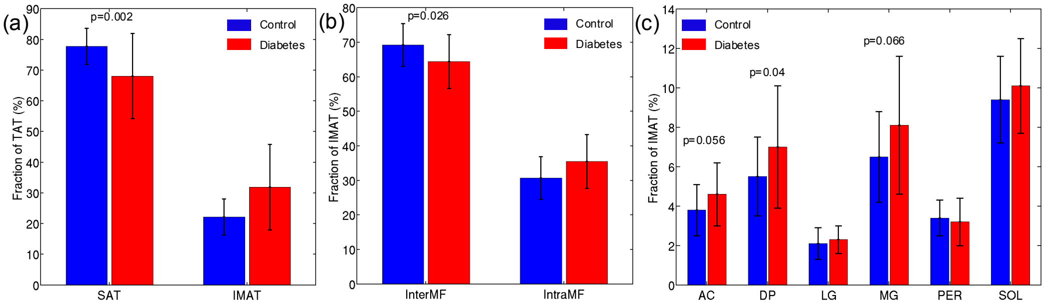

Fig. 3: Statistical analysis results: (a) variation of distribution of TAT between SAT and IMAT compartments, (b) variation of distribution of IMAT between interMF and intraMF compartments and (c) variation of distribution of IMAT between the 6 muscle group compartments for the control and diabetes groups under study .

Discussion & Conclusion: The result of the increase in the relative contribution of IMAT in TAT in diabetics is consistent with previous studies showing an increase in IMAT and decrease in SAT in diabetics compared to controls [1]. To the best of our knowledge, the result about the increase in the relative contribution of intraMF in IMAT in diabetics compared to controls has not been reported in previous studies. This novel finding shows that diabetes might be associated with changes in the adipose tissue distribution not only between subcutaneous and intermuscular regions but also between intermuscular and intramuscular regions. Scanning of more patients would be necessary in order to draw conclusions about changes in the distribution of IMAT within specific muscles. In conclusion, quantitative IDEAL enables the characterization of the regional distribution of muscular fat in type 2 diabetes patients. The characterization of changes in distribution of muscular fat would expand our knowledge for type 2 diabetes risk assessment and could be beneficial in diabetes treatment monitoring (including exercise and diet interventions [13]).

References: [1] Gallagher et al, AJCN 89:807, 2009, [2] Boettcher et al, JMRI 29:1340, 2009, [3] Schick et, MRM 47:720, 2002, [4] Goodpaster AJCN 71:885, 2000, [5] Weis et al, MRM 54:152, 2005, [6] Reeder et al, MRM 51:35, 2004, [7]Yu et al, MRM 60:1122, 2008, [8] Bydder et al, MRI 26:347, 2008, [9] Wren et al, AJR 190:W8, 2008, [10] Karampinos et al, ISMRM 2010, p. 418, [11] Middleton et al, ISMRM 2009, p. 4331, [12] Liu et al, MRM 58:354, 2007, [13] Johnson et al, ISMRM 2010, p. 2632.

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