BODY COMPOSITION VOLUMETRY BY WHOLE-BODY WATER-FAT SEPARATED MRI

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Target audience
Clinicians and researchers interested in the metabolic syndrome.

Purpose: The purpose was to measure body composition with respect to total lean and adipose tissue volume. The distribution of these tissues is of importance in order to study the mechanisms causing the metabolic syndrome. Conventional clinical measures, such as BMI, air displacement plethysmography (ADP) and bioelectrical impedance have strong limitations being indirect measures only partially related to the relevant parameters. In contrast, image-based measures can be derived using direct measurement on the tissue without model assumptions. Since none of the conventional methods are based on 3D data, they cannot be used to determine the distribution of the tissue within various compartments (e.g. visceral and subcutaneous adipose tissue). Water-fat separated MRI (1), using white adipose tissue (WAT) as an internal reference, can be used to determine the adipose tissue volume (2-4), and both total and local adipose tissue can be obtained. The extended method reported allows for the measurements of total lean soft tissue volume (LTV), total adipose tissue volume (ATV) and total soft tissue volume (STV), based on whole-body image data. The measurements were validated by a comparison with ADP, and the precision was determined at different field strengths, resolutions, TRs, TEs on MRI-scanners from different manufacturers.

Materials and Methods: A flowchart illustrating the data flow of the method is shown in Fig. 1. The STV (i.e. the MRI-detectable tissue volume), was calculated by integrating all voxels in a fuzzy tissue mask (FTM), which constitutes a synthetic proton density (PD) map. The FTM was then calculated by locating pure adipose tissue voxels, i.e. non-background voxels with a fat fraction > 95 %, followed by estimating the total intensity bias which was then removed from the fat images (5). The result was a set of intensity corrected fat images (Fc) with the assigned value 1 (100%) for pure adipose tissue. The same operation was repeated for the water images in order to obtain Wc, using voxels with a water fraction > 95 %. This procedure eliminated the T1w induced contrast, and also centered pure water tissue voxels around 1. A binary tissue mask (BTM) was created in order to remove all residual contrast by applying a threshold of 0.5 on the Fc+Wc images. BTM was also extended to include FTM voxels ±1 voxel from the border of BTM assigned to Fc+Wc. Moreover, the total adipose tissue volume (ATV) was calculated as the weighted average of Fc, weighted using the FTM values. This procedure provided a robust ATV estimate. Finally, the lean soft tissue volume was calculated as LTV = STV-ATV. The precision was estimated using MRI images from a total of 39 healthy volunteers using different protocols, field strengths and MRI-systems. Water-fat separation was performed using the inverse gradient method (6, 7). The experimental protocols used and the total number of observations is listed in Table 1. Precision was then estimated using intraclass correlation (ICC), limits of agreement (LOA) and coefficient of variation (CV) calculations. To measure the accuracy, CV and LOA were calculated between ATV and ADP, and the ADP measurement was conducted within one day of the MRI examination.

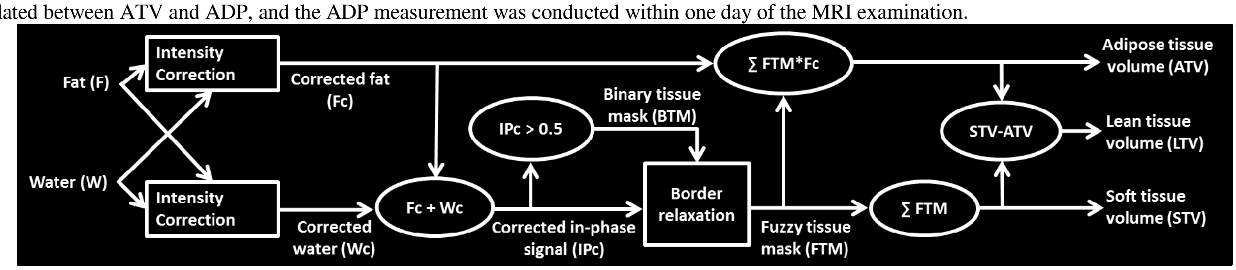

Fig. 1 Flowchart of the data from water-fat separated images to tissue volume estimates. See the Materials and Methods section for more details.

Table 1 Parameters of the protocols used, common parameters are: a flip angle 10°, and 3D SPGR acquisition. The number of stacks was set to get maximal coverage.

Protocol Number	MR-scanner	Coil	Acquired Voxel Size [mm^3]	FOV [mm^3]	Stack Overlap [mm]	Arm Positioning	TEs [ms]	TR [ms]	Observations
1	Philips 1.5 T Achieva	Integrated	3.50x3.50x3.50	530x307x200	30	Above head	2.3/ 4.6	6.6	53+10+6
2	Philips 1.5 T Achieva	Integrated	2.80x2.80x8.00	530x375x88	0	Above head	2.6/ 5.19	8.8	53
3	Philips 3.0 T Ingenia	Anterior, posterior and head phased array	1.75x1.75x1.75	560x336x (146 to 265)	28	Along body	1.15/ 2.3	3.8	10
4	GE 1.5 T Optima 450w	Integrated	3.00x2.70x3.00	500x350x192	30	Above head	2.3/ 4.6	6.1	6

Results: Both ATV and LTV measures showed excellent precision with a lowest ICC of 0.995. The worst CVs between MRI-protocols were 1.09 ± 0.91 % for ATV, and 0.49 ± 0.98 % for LTV. The worst LOA between MRI protocols were from -0.53 to 1.01 L for ATV and -0.73 to 0.60 L for LTV. ATV showed high accuracy in the ADP-MRI comparison with an ICC of 0.984, CV of 4.84 ± 4.20 % and LOA of -3.9 to 2.33 L.

Discussion: The method proved to have high precision over a range of settings, making it suitable for both longitudinal and multicenter studies. Furthermore, the method was shown to be accurate due to the high agreement with ADP. The high agreement between the different protocols also shows a high degree of invariance with respect to image resolution and acquisition technology.

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