

Test-Retest Reproducibility of Whole-body Fat Water Imaging at 3 Tesla Compared to DEXA

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Introduction: Whole-body MRI has great potential for quantifying the amount, type and distribution of adipose tissue to help better understand the metabolic consequences of adipose tissue. Recently, multi-gradient-echo (mFFE) MR acquisitions have been successfully used at 1.5 Tesla to quickly acquire whole-body fat-water imaging data sets [1-2]. Automated segmentation and quantification of such whole-body fat images into subcutaneous and visceral adipose tissue compartments [2] shows great promise as a tool in studies of obesity and other metabolic syndrome diseases such as diabetes. Dual energy x-ray absorptiometry (DEXA) is widely used in studies of body composition, but few direct comparisons of the performance of fat-water MR imaging (FWMRI) to DEXA are available, especially for 3T FWMRI. Here we present test-retest results of scanning 12 obese female subjects using a 3T mFFE whole-body FWMRI sequence as well as DEXA.

Methods: Twelve (5 Caucasian and 7 African American) obese (BMI=34.3±1.8) women were recruited to have MRI and DEXA. All subjects provided written informed consent. MRI scans were performed on a whole-body 3T Achieva scanner (Philips Healthcare, Best, The Netherlands). For MRI, subjects entered the scanner feet-first in a supine position with arms extended above the head. The integrated quadrature body coil (QBC) was used for both transmit and receive. A multi-station protocol with 17 table positions was used to acquire the whole-body data. Each of the 17 stacks consisted of a multi-slice, mFFE acquisition with 12 contiguous 8 mm slices. Other acquisition details include: TR/TE1/TE2/TE3 [ms] = 75/1.34/2.87/4.40; FA=20°; WFS=0.325 pixels (BW=1335.5 Hz/pixel); FOV = 500 mm × 390 mm, acquired matrix size = 252 × 195; acquired voxel size = 2 mm × 2 mm × 8 mm. First order (“auto”) shimming was performed for each slice stack. The total duration of data acquisition was 4 minutes and 16 seconds. Approximately 5 minutes of additional time was needed for table movement, preparation phases at each table position, and for breath holding pauses. Breath holding was performed for table positions covering the waist to the shoulders. Reconstruction of water and fat images from the acquired multi-echo data was performed using a generalized three-point Dixon approach [3]. Visceral and subcutaneous adipose tissue volumes in the trunk region (femoral head to base of lungs) were segmented and quantified by a previously described automated algorithm [2]. DEXA measurements were acquired by a certified densitometrist using a Lunar iDXA whole-body scanner (GE Healthcare, Madison WI). Analysis of DEXA images was performed using enCORE 2007 software version 11.40.004. Scan time ranged from 6.5 – 12.5 minutes depending on the subject’s sagittal thickness. MRI tissue volumes were converted to mass using a density of 0.923 kg/L for adipose tissue [4]. Test-retest measurements were acquired for both FWMRI and DEXA by having the subject stand up from the scanner table before being repositioned for the second scan. Masses for whole-body adipose tissue (WBAT) and total trunk adipose tissue (TTAT) were compared between FWMRI and DEXA. DEXA ROIs (whole-body and trunk) were manually defined to match the MRI. Trunk visceral adipose tissue (TVAT) and trunk subcutaneous adipose tissue (TSAT) were available for FWMRI but not from DEXA. Test-retest measurement variation was calculated as a coefficient of variation (CV) defined as the square root of the mean within-group variance of a one-way ANOVA (with each subject as a group) divided by the grand mean [5]. Scale weight, body mass index (BMI), maximum sagittal thickness, and waist circumference values were collected for each subject. Wilcoxon signed rank tests were used to compare FWMRI and DEXA test-retest differences for WBAT and TTAT and FWMRI and DEXA mean WBAT and TTAT. Pearson and Spearman correlations were calculated between all variables including mean FWMRI measures (WBAT, TTAT, TVAT, TSAT), mean DEXA measures (WBAT, TTAT), difference between FWMRI and DEXA (WBAT, TTAT) as well as scale weight, BMI, maximum sagittal thickness, waist circumference, and race.

Results: Figure 1 shows coronal 1st echo maximum intensity projections from 4 of the 12 subjects (**a, b, c, d**) with the segmented TVAT shown in red. Table 1 lists the test-retest measurement CV and mean ± 95% confidence interval half-widths for the different adipose tissue depots. Because DEXA is a projection imaging method, TVAT and TSAT are not available. Wilcoxon signed rank tests showed no significance between the test-retest differences for FWMRI versus DEXA for WBAT or TTAT, i.e. the CVs are not significantly different. Wilcoxon signed rank tests did show a significant difference between FWMRI and DEXA for mean WBAT (p=0.003) and TTAT (p=0.006). DEXA appears to underestimate WBAT and TTAT compared to FWMRI. No correlations with race were significant. Many other Pearson and Spearman correlations were significant, however, only one variable, FWMRI TSAT, had a significant correlation with the systematic WBAT/TTAT difference between FWMRI and DEXA. For TVAT, only maximum sagittal thickness correlated significantly with both Pearson and Spearman tests. BMI also correlated significantly with TVAT, but only with the Pearson coefficient. Of all anthropometric measures, maximum sagittal thickness correlated with the most variables.

Discussion: This work compares the reproducibility of FWMRI and DEXA for whole-body and abdominal (trunk) adipose tissue measurement. While the coefficient of variation for the two techniques is not significantly different, FWMRI and DEXA systematically disagree on the amount of adipose tissue, with DEXA consistently yielding a lower amount. Results here imply that TSAT may be factor in DEXA’s underestimation. In addition to having reproducibility competitive with DEXA, FWMRI has the important advantage of discriminating and independently quantifying specific AT depots, such as visceral and subcutaneous fat.

References: 1. Börner P et al. JMRI (2007) 25:660-65. 2. Kullberg J et al. JMRI (2009) 30(1):185-193. 3. Berglund J et al. MRM (2010) 63(6):1659-1668. 4. Chowdhury et al. IJORMD (1994) 18(4):219-234. 5. Bland M. Medical Statistics 2nd Ed. Oxford University Press (1995):266-269 ISBN:0192624288.

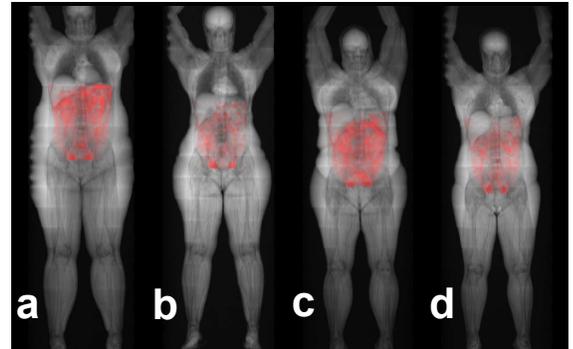


Figure 1. Example maximum intensity projections of mFFE 1st echo magnitude image with segmented trunk visceral adipose tissue (TVAT) shown in red for 4 different subjects (**a, b, c, d**).

	WBAT	TTAT	TVAT	TSAT
FWMRI CV	0.76%	2.26%	2.62%	2.38%
DEXA CV	0.58%	1.35%	N/A	N/A
FWMRI [kg]	49.8 ± 6.0	17.2 ± 2.5	2.61 ± 0.76	14.6 ± 2.0
DEXA [kg]	39.6 ± 4.8	15.7 ± 2.2	N/A	N/A

Table 1. Test-retest measurement coefficient of variation (CV) and grand mean ± 95% confidence interval half-widths in kg for FWMRI and DEXA for whole-body adipose tissue (WBAT), total trunk adipose tissue (TTAT), trunk visceral adipose tissue (TVAT) and trunk subcutaneous adipose tissue (TSAT).