Automatic combined whole-body muscle and fat volume quantification using water-fat separated MRI in postmenopausal women

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Introduction: Two of the greatest health-challenges today are the increasing prevalence of obesity (1-2) and risks in the aging population (3). Quantitative and exact measurements of fat and muscles in the body are important for prevention and diagnosis of diseases related to muscle degeneration and obesity. Manual segmentation methods are well established, but very time-consuming and result in subjective estimations. In recent years, however, automatic methods have been developed (4-5), but validations in different populations are necessary. One subject group of particular interest are females undergoing menopause, where the body composition is changing, as a consequence of the insufficient steroid hormone production.

The aim of this study was to validate combined muscle and fat volume quantification from a single water-fat separated MR-acquisition, in a group of postmenopausal women. Furthermore, test-retest reliability for all measurements was established.

Materials and Methods: *In-vivo* imaging was performed using a Philips Ingenia 3.0 T MR-scanner in 12 female postmenopausal subjects (age 56.5 ± 5.3, range 50 to 68 years, BMI 26.1 ± 2.8, range 22.7 to 30.0). MR acquisitions were performed with a 4 echo 3D gradient-echo sequence with echo times of 1.1, 2.3, 3.5, and 4.6 ms. Repetition time was 5.8 ms with 10° flip angle, acquisition resolution was 2.5 x 2.5 x 4.0 mm^3. The MR protocol was applied repeatedly until whole-body coverage was reached and scan-time was 7 minutes per scan. Each subject was scanned twice, where the subject was removed from the scanner room in between acquisitions. The regional ethics committee approved the study, and written informed consent was obtained from all subjects prior to study entry.

Water and fat image volumes were calculated by an in-house implementation of the IDEAL algorithm (6). The water and fat image volumes were intensity inhomogeneity corrected using the algorithm described in (7-8). Subsequently, ground truth labels for fat compartments: visceral adipose tissue (VAT), and abdominal subcutaneous tissue (ASAT), as well as muscle compartments: left lower leg, right lower leg, left posterior thigh, right posterior thigh, left anterior thigh, right anterior thigh, left abdomen and right abdomen, were registered to the acquired volumes using non-rigid atlas based registration, as described in (8).

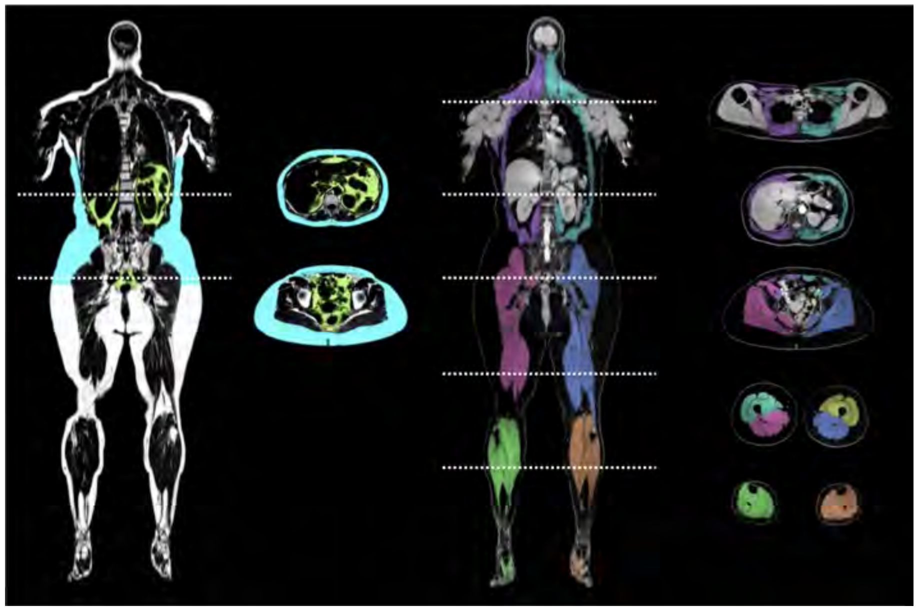

Figure 1: *Coronal and transverse sections of a 51-years old female subject.* ***(a)*** *intensity-corrected fat image with fat segmentations using overlay colours,* ***(b)*** *intensity-corrected water image with muscle segmentations using overlay colours.*

Finally, quantification of fat and muscle volumes were performed using the registered labels and the intensity corrected fat and water images. Segmentations were performed using AMRA Analyzer (AMRA AB, 2014).

Descriptive statistics (mean ± SD) were calculated for all 10 measurements. Test-retest reliability was calculated using Bland-Altman analysis (*mean of difference*, and *limits of agreement*) as well as *coefficient of variation* (CoV). Statistical analysis was performed in SPSS 19 (IBM, 2010).

Results: Figure 1 shows sample segmentations from one of the subjects. The mean differences between the acquisitions were -1.4 % for VAT, -0.6 % for ASAT, -0.9 % for left lower leg, -0.7 % for right lower leg, -0.6 % for left posterior thigh, -0.2 % for right posterior thigh, -0,4 % for left anterior thigh, -0.2 % for right anterior thigh, 0.4 % for left abdomen and -1.0 % for right abdomen. Complete statistics are presented in Table 1.

Discussion and Conclusion: Whole-body regional fat and muscle segmentation could be performed with excellent test-retest reliability, in images from a single 7-minues MR-scan. These results suggest that combined whole-body fat and muscle quantification are achievable from a single rapid MR-acquisition.

Table 1: *Results from Bland-Altman analysis and * coefficient of variation for all test-retest measurements. Measurements in L.*

		Test	Retest		Bland-Altman analysis		
		Mean ± SD	Mean ± SD	CoV*	Mean of difference	Lower bound	Upper bound
Fat	Visceral adipose tissue	2.73 ± 1.54	2.70 ± 1.53	2.6 %	- 0.04	- 0.23	0.16
	Abdominal subcutaneous tissue	7.83 ± 2.23	7.79 ± 2.22	1.0 %	- 0.04	- 0.34	0.25
Muscle	Left lower leg	1.56 ± 0.22	1.55 ± 0.22	0.7 %	- 0.01	- 0.04	0.02
	Right lower leg	1.59 ± 0.22	1.58 ± 0.21	0.6 %	- 0.01	- 0.04	0.02
	Left posterior thigh	2.81 ± 0.35	2.80 ± 0.36	0.5 %	- 0.02	- 0.05	0.02
	Right posterior thigh	2.75 ± 0.38	2.75 ± 0.38	0.5 %	- 0.01	- 0.05	0.04
	Left anterior thigh	1.46 ± 0.22	1.45 ± 0.22	0.6 %	- 0.01	- 0.03	0.02
	Right anterior thigh	1.54 ± 0.23	1.52 ± 0.23	0.7 %	- 0.02	- 0.04	0.01
	Left abdomen	2.62 ± 0.35	2.63 ± 0.34	0.5 %	0.01	- 0.04	0.06
	Right abdomen	2.77 ± 0.36	2.74 ± 0.31	1.3 %	- 0.03	- 0.18	0.11

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