Quantification of abdominal fat accumulation during hyperalimentation using MRI

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Introduction:

There is an increasing demand for imaging methods that can be used for automatic, accurate and quantitative determination of the amounts of abdominal fat. Such methods are important as they will allow the evaluation of some of the risk factors underlying the 'metabolic syndrome'. The metabolic syndrome is becoming common in large parts of the world, and it appears that a dominant risk factor for developing this syndrome is abdominal obesity. Subjects that are afflicted with the metabolic syndrome are exposed to a high risk for developing a large range of diseases such as type 2 diabetes, cardiac failure, and stroke. The aim of this work was to quantitatively investigate the effects of intense over-eating on the fat accumulation in the abdominal regions in women and in men, using a novel MR and post-processing scheme. Automation of the procedures was important in order to perform the measurements independently of the operator.

Methods:

Subjects and intervention protocol: By local advertising we recruited 12 males and six females as volunteers for the study. All participants had to be willing to accept a twofold increase in the daily caloric consumption with the goal of gaining 5-15% of weight. The subjects were asked to eat at least two fast-food-based meals a day, preferably at well known fast food restaurants such as McDonald's and Burger King. Physical activity was not to exceed approximately 5000 steps per day. If a study subject reached the maximally allowed weight-gain of 15% he or she terminated the study as soon as possible by re-performing the same study investigations that were performed at baseline, [1]. The study design was approved by the local ethics committee.

Magnetic resonance imaging protocol: Images were acquired before and after the intervention period from the level of the diaphragm to the bottom of the pelvis using a 1.5 T Philips Achieva MR-scanner (Philips Medical Systems, Best, The Netherlands). A four-element sensitivity encoding (SENSE) body coil was used to obtain magnitude and phase images from two different stacks using a field of view (FOV) of 290 x 410 x 200 mm^3, 5 mm slice thickness and 2.14 x 2.16 mm^2 in-plane resolution reconstructed to 1.6 x 1.6 mm^2. In cases where two stacks in the superior-inferior direction provided insufficient volume coverage, an extra image stack was acquired using the quadrature body coil (QBC, integrated in the bore) using a FOV of 290 x 410 x 50 mm^3. The images were obtained at two different echo times (TE:s) using a dual echo, multi slice, spoiled, fast gradient echo pulse sequence. The first echo was obtained using TE1 = 2.3 ms with the water and fat signals out of phase, and the second using TE2 = 4.6 ms with the water and fat in phase. The repetition time (TR) was 286 ms. Data was collected using breath-hold technique (28 s using the SENSE body coil and 8 s using the QBC) with CLEAR reconstruction.

Quantification of intra abdominal fat volume: Fat and water images were calculated using Dixon reconstruction [2] after phase unwrapping using the inverse-gradient method [3,4]. The images were corrected for field intensity inhomogenities by interpolating between known fat voxels using normalized convolution [5]. The abdominal adipose tissue was then segmented into three different types: subcutaneous, intraabdominal and retroperitoneal adipose tissue by registering a manually defined general prototype to the data using the morphon method [6]. This non-rigid registration process uses the water image which contains structures with less variability than the fat image. The registration result was then used to classify each voxel into one of the three different types of adipose tissue compartments. Finally, the fat volume of each adipose tissue compartment was determined by integrating the intensity corrected fat image for the corresponding tissue type. Description and validation of the complete quantification and registration method have been presented in [7].

Results:

Subject weights in the intervention group increased from 67.6 ± 9.1 kg to 74.0 ± 11 kg ($p < 0.001$) with no gender difference with regard to this or with respect to changes of total abdominal fat volume or waist circumference. The absolute increase in fat volume in the abdominal region (i.e. subcutaneous, intraabdominal and retroperitoneal fat) was identical in men and women (<u>MEN</u>: from 4.53 ± 2.0 L to 5.88 ± 1.9 L i.e. an increase in volume of +1.35 ± 0.7 L; <u>WOMEN</u>: an increase from 5.12 ± 1.4 L to 6.47 ± 2.0 L, i.e. an increase of +1.35 ± 0.72 L, with no significant difference for comparison of genders). However, the localization of the accumulated fat volume determined by MRI differed between genders. In men, 41.4 ± 0.09 % of the increase in the abdominal fat volume was intraabdominal whereas the corresponding figure for women was 22.7 ± 0.1 % ($p < 0.0001$). A single slice of the image volume after fat quantification before and after the intervention period is shown in Fig 1.

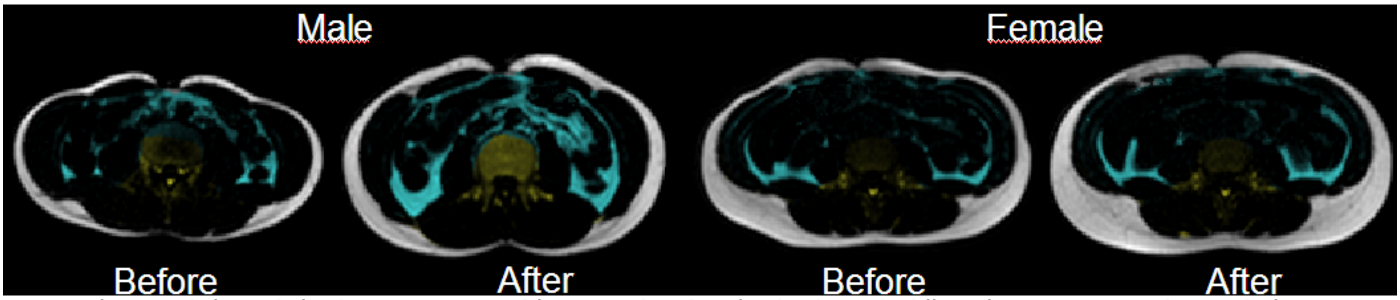

Fig 1. *MR fat images before and after the intervention period from one male and one female subject. The different fat compartments is shown in the fat image using cyan color for intra abdominal, yellow for retroperitonal, and white for subcutaneous adipose tissue. Note that only one selected slice of the complete three dimensional volume is shown, and that the image intensity corresponds to fat signal strength.*

Conclusions:

The main conclusions of this study were the following. (1) One important conclusion was the high suitability of a completely automatic procedure for fat quantification. (2) A particularly novel aspect is the compensation scheme that was used to avoid partial volume effects in mixed fat/water voxels. This was obtained using an unconventional intensity correction method. (3) Finally, it appears that there are very significant differences in the mechanisms whereby fat is accumulated in the abdominal region in women, compared to how it is stored in men. In summary, the study highlighted the suitability of MRI for accurate and user independent investigation of the compartmentalization of fat deposits in the body automatically.

References:

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