Quantification of Adipose Tissue Depots in the Obese Thigh During Weight Loss using Dixon Method

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Introduction

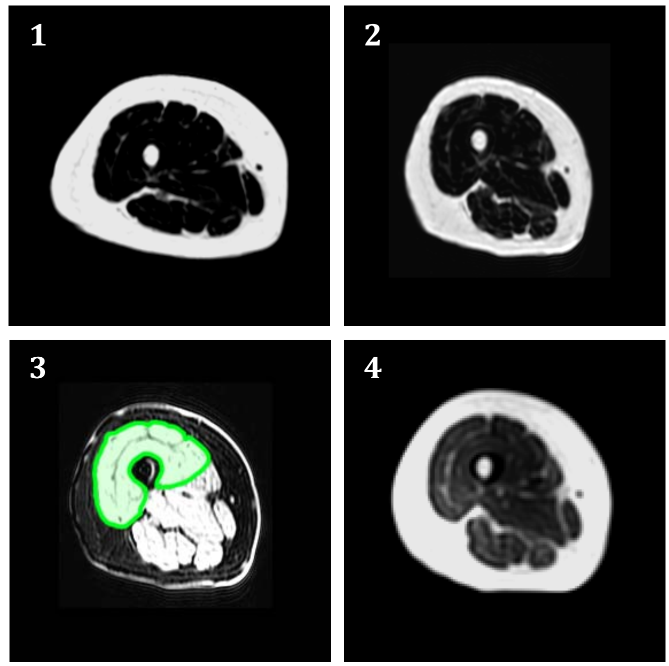
Obesity is a leading cause of cardiovascular disease and many metabolic diseases, such as diabetes. While weight loss reduces adiposity and can lead to a decreased risk for these diseases, it may also result in loss of bone and muscle mass, especially in older adults [1]. MRI can be used to assess the effectiveness of weight loss interventions investigating the impact of diet and exercise on body composition. MRI has been used in musculoskeletal imaging to quantify subcutaneous (SAT) and intermuscular (IMAT) adipose tissue with T1 weighted imaging [2,3], and intramyocellular (IMCL) and extramyocellular (EMCL) fat content with single-voxel spectroscopy [4] and fat selective RF excitation pulses [5,6]. In this work, a two-point Dixon method [7] is used to separate fat and water signals in order to quantify adipose tissue depots, as well as muscle mass, before and after a weight loss intervention for older, obese women.

Methods

Intervention: Fifteen older, obese women (mean age: 63.8 ± 3.4 years; weight: 191.8 ± 27.9 lbs; BMI: 32.9 ± 4.1) were scanned prior to entering a six-month weight loss intervention program. The double-blind randomized study included an energy-restricted diet (~1500 kcal/d), low-intensity exercise (walking and stretching) and a powdered supplement. Seven of the subjects were randomly assigned a carbohydrate supplement (maltodextrin; CARB) for control, while the other eight received a whey protein supplement (PRO). Following the intervention, subjects were scanned again to quantify changes in muscle and fat content. The aim of the study was to assess the effect of the supplements on differences in body composition changes between the two groups.

Imaging: Subjects were scanned on a General Electric 1.5T Signa Excite whole-body scanner using a phased array torso coil strapped around the thigh. A spoiled gradient-recalled echo sequence was used to acquire in- and out-of-phase images for a two-point Dixon fat separation technique. Images were acquired in 10 mm slices over the middle third of each subject's femur (about 16 slices), and were registered from the endpoints of the bone for comparison after weight loss. A FOV of 48 cm and matrix size of 256x256 resulted in an in-plane resolution of 1.875 mm. The entire acquisition took 25 seconds.

Processing: Fat separated images (shown in Figures 1 and 2) were segmented with operator-drawn ROIs around the entire thigh and around the muscles using WinVessel (Ron Meyer, MSU). Thresholding was done based on the intensity of SAT and the histogram of intensities across the image in order to isolate and quantify SAT and IMAT depots [8,9,10]. To quantify intramuscular fat (IMCL + EMCL) in the quadriceps femoris muscle group, ROIs were drawn around the muscle group (demonstrated in Figure 3), and fat content was determined by comparing the average signal to the average signal from SAT [5]. Values were averaged over the middle third of the femur, which can provide a representative measure of the subject's total body composition [10].



Figures: (1) pre-intervention and (2) post-intervention fat only images; (3) post-intervention water only image with ROI around quadriceps; (4) T1-weighted image for comparison

Results

Following the six-month weight loss intervention, the group of women that received the protein supplement lost more weight than the group with the carbohydrate supplement (PRO: 10.6 ± 6.7 compared to CARB: 5.0 ± 4.0 percent of total body weight lost; $p = 0.078$). The PRO group also lost more SAT (PRO: 26.7 ± 12.9 versus CARB: 7.5 ± 9.1 percent change in total volume; $p = 0.006$), IMAT (PRO: 16.3 ± 14.0 versus CARB: 11.8 ± 8.5 percent change in total volume; $p = 0.475$), and intramuscular fat (PRO: 15.8 ± 17.3 versus CARB: 8.3 ± 10.7 percent change in volume in quadriceps femoris; $p = 0.348$). In addition to losing the most weight and adipose tissue, the PRO group also had the largest increase in the percentage of muscle over thigh volume (PRO: 7.5 ± 5.8 versus CARB: 5.3 ± 5.1 change in percent muscle over entire thigh; $p = 0.108$). These trends demonstrate the benefit of the protein supplement for weight loss, but it should be noted that only the weight and SAT measures were statistically significant. The statistical insignificance of the other trends presented can be mostly attributed to the small sample size, where large variations lead to the high p-value.

Discussion and Conclusions

Combating obesity through weight loss can lead to improvements in health and quality of life, but it can also lead to degradation in bone and muscle, which can lead to impaired physical function in older adults. Supplementing a weight loss program with protein provided in this study showed an increase in weight lost during the intervention, while attenuating the loss of muscle mass that normally accompanies weight loss. Adipose tissue depots in the thigh—SAT, IMAT, and intramuscular fat—are used for estimating obesity and obesity related health risks, and it was shown that using a two-point Dixon technique with MRI is an effective method for measuring adipose tissue in the thigh. Dixon fat separated images allowed for improved segmentation of SAT and IMAT over conventional T1 weighted imaging (Figure 4), as well as quantification of intramuscular fat over an entire muscle group without the need for a lengthy spatial-spectral RF excitation pulse. In summary, this method can be utilized as a fast and effective method for monitoring changes in body composition during weight loss.

References

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