In vivo Measurement of Body Composition Using Proton Magnetic Resonance Spectroscopy

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Introduction

In vivo quantification of body composition is important for studying obesity, diabetes, and other metabolic disorders. By quantifying water and lipid resonances, proton MR spectroscopy offers a highly sensitive, quantitative measure of body water and lipids. Because of its non-invasiveness and fast throughput, MRS has become increasingly used in both clinical and laboratory settings for evaluation of body composition. Separate groups have examined *in vivo* correlation between MRS derived body compositions with chemical analysis and demonstrated a strong correlation between the two methods [1,2]. In this study, we examined the relevance of the MRS measurements to field measurement (weight) using *ex vivo* tissue samples (fat and muscle). We then demonstrated the usefulness of MRS for monitoring alterations of body fat content in a rat model of obesity.

Methods

Validation. A number of fat (white and brown) and muscle tissues were isolated post-mortem from adult rats and weighed before MRS measurements. On a 4.7T/40cm magnet, proton spectroscopy was collected using a volume coil and a pulse-acquire sequence (TR=10 s) from all the tissue samples alone as well as on samples that combined muscle and fat tissues (making a total of 18 tissue samples). We adopted the quantification method used by Cockman MD, et al [2] using benzene as an external reference for absolute quantification of the spectra. With the assumption that fat free tissue mass (FFM = total tissue mass – tissue water mass) is proportional to tissue water mass (WM) (WM = 0.73 FFM) [1], total tissue mass can be calculated based on water and lipid resonances. Percent fat was then derived from lipid mass calculated from lipid resonance divided by the total tissue mass. The analysis of all the MR spectra was performed using in-house software to calculate the area under the curve for each resonance. For the validation study, the correlation of (1) MRS-derived tissue mass versus tissue weight, and (2) MRS-derived percent fat versus the percent fat calculated from tissue weights, was evaluated by calculating the simple correlation coefficient, r, and performing a simple linear regression.

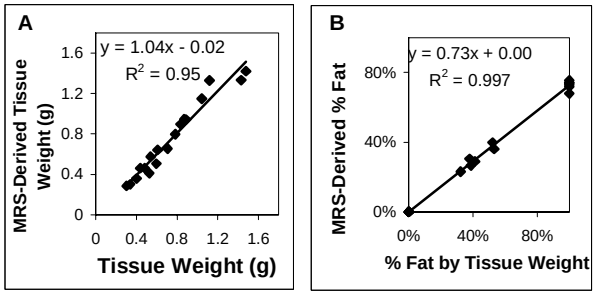

Figure 1

Rat model of obesity. Ghrelin is an endogenous ligand for growth hormone secretageogue (GHS) receptor. It has been shown that ICV administration of ghrelin induces adiposity in rats [3]. Male rats at age 9-10 weeks were randomized into two groups (N=7/group) with equal mean body weight receiving either vehicle or ghrelin. Ghrelin was infused intracerebroventricularly (ICV) at a dose of 12nmol / kg•day (12 µl/day) for 14 days using mini pumps. Body weights were measured every 1-3 day throughout the study. On day 14, MRS was performed over the whole body of conscious rats restrained in a cylindrical restrainer. Upon completion of MRS experiment, rats were euthanized and epididymal fat pads (EFP) were collected and weighed.

Results

Validation. In proton MR spectra, besides the resonance from benzene, two resonances (water, lipids) were observed from fat pads, while only one resonance (water) was detectable from muscle samples. Using *ex vivo* tissue samples including fat only, muscle only, and fat and muscle combined, we observed a strong linear correlation (r = 0.98 ± 0.047) between the MRS derived tissue weights and field method measured tissue weights (Figure 1A). In order to evaluate the validity of using MRS to quantify fat content in body composition, we also examined the correlation between MRS derived percent fat based on lipid resonance to the percent fat calculated from tissue weights. Again, a strong linear correlation was observed with correlation coefficient r = 1.00 ± 0.015 (Figure 1B)

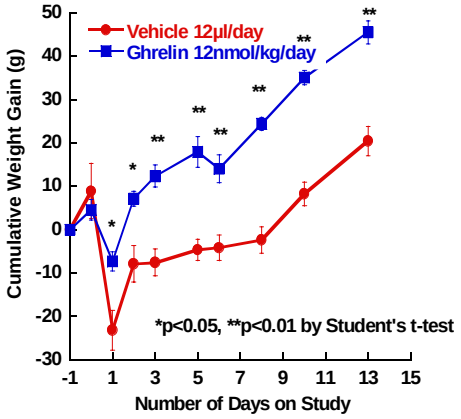

Figure 2

Rat model of obesity. Rats gained weight throughout the two-week period of the study with the exception on day 1. The increase in body weight was significantly higher in the rats receiving ICV infusion of ghrelin (Figure 2). The average body weight gain was 45.6 ± 2.6 g following 14-day ghrelin infusion, comparing to 20.5 ± 3.4 g weight gain in the control group. Percent body fat measured by MRS on day 14 showed that rats receiving ghrelin infusion had significantly higher fat content (Figure 3) suggesting that the increase in body weight was largely due to an increase in fat mass. In agreement, the average EFP weight of the rats administered with ghrelin was 33 % more than that of the control rats.

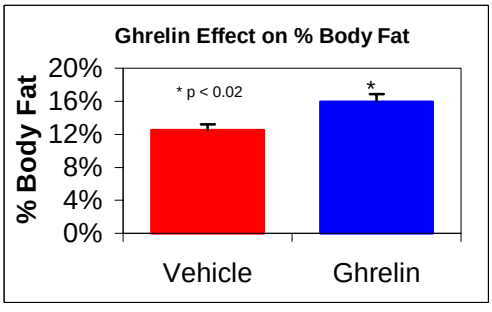

Figure 3

Conclusion

The study demonstrated that proton MRS is a powerful tool for in vivo quantification of body composition to evaluate body fat content. Because the technique is non-invasive and highly sensitive it allows fast throughput measurement on conscious animals for either acute or longitudinal studies.

References

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[3] Tschop M, et al., Nature 407:908-13 (2000)