# Properties of brown and white adipose tissues measured by $^1$H MRS

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**Introduction:** Brown adipose tissue (BAT) is a topic of great interest in obesity and metabolism research. While white adipose tissue (WAT) is primarily associated with energy storage, BAT is involved in energy expenditure and thermogenesis (**1**). BAT is currently identified with positron emission and computed tomography (**2**), but cost and radiation concerns limit its use in investigational studies. It is possible that MR spectroscopy may allow differentiation of BAT from WAT (**3**). In this study we explore potential MR signatures that differentiate BAT and WAT.

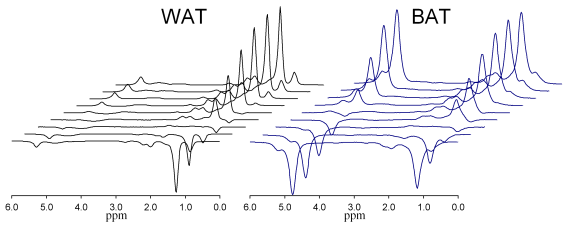


**Figure 1:** Change in WAT and BAT MRS with increasing TI (50, 100, 200, 300, 400, 600, 1000, 2000 and 4000 ms).

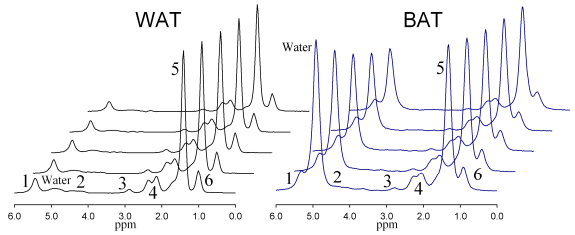


**Figure 2:** Change in WAT and BAT MRS with increasing TE (13, 18, 23, 28, and 33 ms).

**Methods:** All animal research was conducted in accordance with the local Institutional Animal Care and Use Guidelines. Excised tissues of interscapular BAT and gonadal WAT were obtained from mice carcasses from different cohorts and pooled within each group in a single 1.5 ml microtube. The excised adipose tissues were pooled into 4 BAT and 3 WAT tubes. In each of the samples, $^1$H MR STEAM spectra (TR 5000ms, 4 x 4 x 4 mm, TM 6 ms with 16 signal averages) were acquired on a clinical 3T system (GE Signa EXCITE HD, GE Healthcare, Waukesha, WI) using a 3 cm diameter birdcage coil. All scans were conducted at room temperature. Five STEAM spectra were acquired at progressively longer TEs of 13, 18, 22, 28 and 33 ms to allow calculation of T2 and T2-corrected area of the individual spectral peaks. To measure T1 spectra were collected at minimum TE of 13 ms and TIs of 50, 100, 200, 300, 400, 600, 1000, 2000 and 4000 ms. There was no water saturation, and spatial saturation bands around the voxel were disabled to ensure a uniform spectral response across the frequency range of interest. The spectra were analyzed using the AMARES algorithm (**4**) included in the MRUI software package (**5**). Each of the resonance peaks present in the fat $^1$H MR spectrum represents a distinct proton moiety (**Table 1**) allowing the type of triglyceride present in terms of the number of −CH=CH− double bonds per molecule (ndb), and number of double bonds separated by a single $CH_2$ (nmidb - number of methylene-interrupted double bonds) to be estimated (**6**). The fatty acid chain length (CL) was fixed at 17.5. In BAT, the signals from peaks 3, 4, 5 and 6 were use to determine ndb and nmidb, whereas in WAT peaks 1, 3, 4, 5 and 6 were used. Peak 1 was obscured by the water peak in BAT, and peak 2 is strongly j-coupled giving lower than expected peak area (**7**). The mean T1, T2 of the water and fat peaks and mean ndb and nmidb were compared for the 7 sample tubes.

**Results:** **Figure 1** shows the typical signal variation with TI measured in single WAT and BAT samples, and **Figure 2** shows signal variation with TE in the same tissues. **Table 1** shows the mean T1, T2 and T2-corrected peak areas of WAT and BAT. The T1 and T2 of the multiple fat peaks were similar for both BAT and WAT. However, differences were seen in the water peak. In WAT, water is a small component of the total signal, but in BAT the water signal is of similar magnitude to the fat signal in BAT. Also the T1 of water in WAT is almost double that of BAT. For BAT, the peak areas of visible fat peaks (peaks 3, 4, 5 and 6) gives ndb = 2.7 and nmidb = 0.7, while for WAT the areas peaks 1, 3, 4, 5 and 6 in the fat model gives ndb = 3.3 and nmidb = 1.0 indicating that BAT is more saturated than WAT.

**Conclusions:** There are several key imaging signatures of BAT and WAT (T1 relaxation of water component, triglyceride saturation, fat fraction) that may allow differentiation on MR imaging.

**Refs: 1.** Himms-Hagen J. *Can Med Assoc J* 121:1361-64, 1979 **2.** Lee P, et al. *N Engl J Med* 361:418, 2009 **3.** Branca RT, Warren WS. *Mag Reson Med*. 2010 (Epub ahead of print) **4.** Vanhamme L, et al. *J Magn Res* 129:35-43, 1997 **5.** Naressi A, et al. *MAGMA* 12: 168-76, 2001 **6.** Hamilton G, et al. *NMR Biomed*, 2010 (Epub ahead of print) **7.** Hamilton G et al, J *Magn Reson Imag* 20:145-52, 2009.

**Table 1:** Relative magnitude of triglyceride peaks given by theory, and mean T1, T2 and Measured Peak Area of Brown and White Adipose Tissue.

| Peak | *In vivo* ppm | Location | Assignment | Relative Magnitude | WAT T1 (ms) | WAT T2 (ms) | WAT Measured Signal | BAT T1 (ms) | BAT T2 (ms) | BAT Measured Signal |
|---|---|---|---|---|---|---|---|---|---|---|
| **1** | 5.3 ppm | 5.29 ppm<br>5.19 ppm | -C**H**=C**H**-<br>-C**H**-O-CO- | ndb*2<br>1 | 421 | 44.1 | 0.127 | - | - | - |
| **Water** | 4.8 ppm | 4.8 ppm | **$H_2O$** | - | **1053** | 21.7 | **0.124** | **618** | 21.1 | **1.605** |
| **2** | 4.2 ppm | 4.2 ppm | -C**$H_2$**-O-CO- | 4 | 154 | - | - | - | - | - |
| **3** | 2.75 ppm | 2.75 ppm | -CH=CH-C**$H_2$**-CH=CH- | nmidb * 2 | 284 | 46.2 | 0.027 | 219 | 41.4 | 0.016 |
| **4** | 2.1 ppm | 2.24ppm<br>2.02 ppm | -CO-C**$H_2$**-$CH_2$-<br>-C**$H_2$**-CH=CH-C**$H_2$**- | 6<br>(ndb-nmidb)* 4 | 202<br>249 | 51.9 | 0.238 | 189<br>247 | 55.3 | 0.216 |
| **5** | 1.3 ppm | 1.60ppm<br>1.30ppm | -CO-$CH_2$-C**$H_2$**-<br>-(C**$H_2$**)$_n$- | 6<br>[(CL-4)*6]-(ndb*8) + (nmidb*2) | 240<br>280 | 54.7 | 1.000 | 239<br>278 | 51.8 | 1.000 |
| **6** | 0.9 ppm | 0.90 ppm | -($CH_2$)$_n$-C**$H_3$** | 9 | 543 | 80.1 | 0.147 | 567 | 61.5 | 0.149 |