Composition of Adipose Tissue and Marrow Fat by 1H MR Spectroscopy at 7 Tesla

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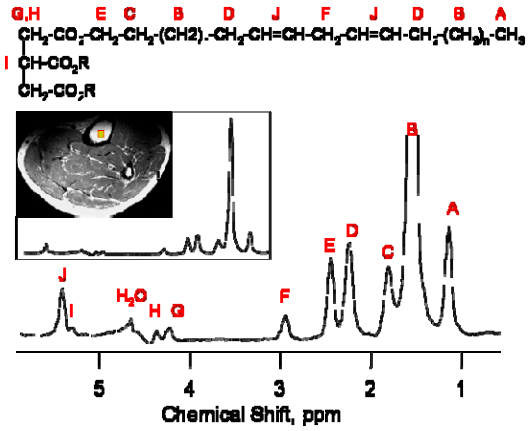
Introduction: Composition of adipose triglycerides is of intense public and scientific interest because of interactions among diet, fat composition, and health. Predisposition to cancer, coronary disease, and type 2 diabetes has been attributed to saturated fats (1). ^{1}H spectroscopy has been widely applied for detection of intracellular and extracellular fat content in skeletal muscle (2). Earlier studies used ^{1}H NMR spectroscopy for analysis of fat composition in tissue extracts (3). However, it is difficult to resolve the signals from protons on or adjacent to double bonds in vivo at 1.5 or 3.0 T. ^{13}C NMR offers superior chemical shift dispersion, and fat composition analysis in humans has been available for some time (4-6). The ability to noninvasively monitor triglyceride composition using proton spectroscopy would allow simple integration with other procedures and would have clinical research applications. An approach to measuring extracelluar fatty acid composition at 7 Tesla was developed and applied in normal human subjects.

Methods: Protocols were approved by the Institutional Review Board. Healthy adults (n = 10) were studied supine in a 7T system (Achieva, Philips Medical Systems, Cleveland, OH) using a partial volume quadrature transmit/receive coil. Axial, coronary and sagittal T2-TSE images were acquired for planning. Single-voxel STEAM (6x6x6 mm, TR 2000 ms, TE 20 ms, NSA 4 scans) was used. To correct for relaxation effects in individual resonances, T1 and T2 values were measured by using inversion-recovery and varying TE techniques, respectively. Since the fraction of fat that is saturated (f_{sat}), monosaturated (f_{mono}) and polyunsaturated with 2 double bonds (f_{poly}) amounts to ~97-98% of total fat, we assumed $f_{sat} + f_{mono} + f_{poly} = 1$. The fraction that is polyunsaturated, f_{poly}, can be determined directly from the relative area of the resonance of the "bridging" diallyllic protons (resonance F), with respect to the resonance of methylene protons α to COO (resonance E): f_{poly} = area (F/E). The f_{mono} value can be evaluated by f_{mono} = 0.5 * area (D/E) - f_{poly}. The remaining unknown is the saturated fatty acid, which can be derived by difference from 1. The fraction of fatty acids that are 16 carbons vs. 18 carbon, with the assumption that $f_{16C} + f_{18C} = 1$, was determined from the relative areas of the methylene $(-CH_2-)_n$ and methyl resonances after correcting for reduction in the methylene signal (area B) due to mono- and polyunsaturated fats.

Results and Discussion: A typical ^{1}H NMR spectrum of human bone marrow together with fatty acids resonance assignments are shown in the Figure. Letters A – J refer to the protons in the molecular structure. The methylene proton E, α to the COO, was chosen for reference because the chemical shift is close to that of resonance F and D, reducing frequency-dependent chemical shift offsets in spatially-localized spectra. The composition of marrow and subcutaneous fat was not significantly different. By direct chemical analysis (7), the fraction of fat that was saturated, monounsaturated and polyunsaturated is 0.26, 0.57 and 0.17, respectively. Using these literature standards, NMR overestimated the fraction of fat that is polyunsaturated and underestimated the fraction that is monounsaturated. The fraction of fat that is 16 carbon (0.28 from reference 7) was similar to NMR estimates.



Fatty Acids Composition in Marrow and Subcutaneous Fat.

Relative concentration	Marrow	Subcutaneous
Saturated (f_{sat})	0.28 ± 0.09	0.29 ± 0.10
Monounsaturated (f_{mono})	0.46 ± 0.07	0.49 ± 0.09
Polyunsaturated (f_{poly})	0.26 ± 0.09	0.24 ± 0.11
Chain length		
Fraction 16 carbon (f_{16C})	0.30 ± 0.06	0.34 ± 0.08
Fraction 18 carbon (f_{18C})	0.70 ± 0.11	0.66 ± 0.15

Conclusion: Our study on human calf fat tissues demonstrated that the 7T MRS, due to high spectral resolution, offers a simple method to obtain detailed information on fatty acid composition in subcutaneous adipose tissue and marrow.

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