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SHORT REPORT

Fat may affect magnetic resonance signal intensity and brain tissue volumes

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Summary Obesity/overweight is reported to affect MR-measured brain tissue volume and white matter (WM) signal intensity. This study investigated possible effects of fat on these measures, using pig fat on three participants at a 4 T magnet. Grey matter volumes in the presence of fat were lower than baseline measures. Total WM volumes in the presence of fat were higher than baseline measures. WM hypo-intensities on T1-weighted images were higher in the presence of fat than baseline measures. Therefore physical effects of head fat of obese/overweight individual may at least, partly contribute to the association of obesity/overweight with MR structural measures.

Several magnetic resonance imaging (MRI) studies reported an association of obesity/overweight with abnormalities in brain tissue volumes: smaller grey matter (GM) volumes [1—8], lower GM densities [9], and larger white matter (WM) volumes [10] than the corresponding measures for normal weight individuals. Similarly, increased incidence of WM signal hyper-intensities on T2-weighted images have been linked to obesity/overweight [11].

Generally the associations of obesity/overweight with the MR-observed abnormalities of brain tissue measures in these publications have been interpreted to reflect altered neurobiology in association with obesity/overweight, which constitutes

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a potentially increased risk for cognitive decline or development of dementia. However, physical effects of fat on MR-measured brain volumes and WM signal quality have not been assessed. This is imperative because obese/overweight individuals are expected to have more fat deposits on the head than normal weight individuals; and if fat has an adverse effect on these measures, that effect could be more pronounced in obese/overweight individuals as compared to normal weight individuals. In a recent report we demonstrated that fat tissue superficially placed in the vicinity of an MR spectroscopy voxel reduced metabolite signal strengths [12]. In this report, physical effects of the superficial fat on MR-measured GM and WM volume measures as well as on WM hypo-intensities on T1-weighted images (which is equivalent to hyper-intensities on T2-images) of the human brain are assessed.

The structural MRI data acquired for the MR spectroscopy experiments that demonstrated the physical effects of fat on metabolite signal strengths [12] were used for this report. The data were acquired at 4 T (Bruker MedSpec system, Ettlingen, Germany), from three healthy male volunteers (aged 30, 31 and 55 years) with BMI of 25.9, 23.5 and 25.6 kg/m^2, respectively. Each participant was scanned first without fat and then with two 0.7 cm thick layers of pig back fat: one layer was placed beneath the occiput and the other on the forehead. All participants signed a formal written approved consent by the committee on human research at the University of California, San Francisco.

T1-weighted images were segmented into GM, WM and cerebrospinal fluid (CSF) tissue volumes using two different methods: the expectation maximization segmentation (EMS) technique [13] and the publicly available volumetric segmentation and cortical surface reconstruction methods provided by FreeSurfer v 5.1 (e.g., [14,15]). Total GM, WM, CSF volumes as well as intra-cranial volume (ICV) were estimated from the EMS data, while FreeSurfer reconstructed 72 small cortical regions of interest, which were appropriately combined to yield temporal, frontal, occipital, and parietal GM volumes. FreeSurfer also segmented WM hypo-intensities on the T1-weighted images; i.e., voxels within WM regions with signal intensities lower than the threshold level for WM.

The EMS segmented data of the three participants are shown in Table 1. The mean difference in total GM volume when subtracting the fat-layer-free (baseline) volumes from the volumes observed in the presence of fat was $-0.8 \pm 0.4\%$. On the other hand, the mean difference for total

Table 1 Total GM, WM, CSF and ICV volumes from EMS segmentation (in mL) for scans with and without externally placed fat layers.

Tissue	Participant 1			Participant 2			Participant 3			Mean ± standard deviation across participants	
	W/o fat	With fat	% diff	W/o fat	With fat	% diff	W/o fat	With fat	% diff	W/o fat	With fat
Total GM	859.0	850.9	−0.9	901.2	891.4	−1.1	777.5	774.4	−0.4	845.9 ± 62.9	838.9 ± 59.4
Total WM	447.4	454.5	+1.6	477.3	481.3	+0.8	414.5	420.7	+1.5	446.4 ± 31.4	452.1 ± 30.3
Total CSF	463.4	462.8	−0.1	442.2	442.9	+0.2	347.5	345.1	−0.7	417.7 ± 61.7	416.9 ± 63.0
ICV	1769.8	1768.1	−0.1	1820.7	1815.5	−0.3	1539.5	1540.2	0.0	1710.0 ± 149.9	1708.0 ± 147.2

ICV: intracranial volume; W/o: without.