Water-Fat Separated MRI for Detecting Increased Fat Infiltration in the Multifidus Muscle in Patients with Severe Neck Problems due to Chronic Whiplash Associated Disorder

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Introduction: Today there exist no effective tools of describing patients suffering from chronic whiplash associated disorders (WAD). This is why diagnosis is based on the patient's subjective description in combination with clinical examinations. The multifidus muscle is a deep muscle close to the vertebrae, rich of muscle spiders and thereby important both for the segmental neck stabilization and for the proprioceptive input from the neck. Previous studies has shown increased fat infiltration in the multifidus muscle in patients suffering from severe WAD, compared to healthy controls, which may be an indication of injury from the trauma[4]. The purpose of this study was to investigate if increased fat infiltration in the multifidus muscle could be found in patients with severe WAD compared to healthy controls using water-fat separated MRI.

Methods: 31 patients (14 men, 17 women, mean age 41.5, SD 10.9, range 20.7-62.7) with chronic (>6 month) clinically verified whiplash associated disorders (WAD) and 31 healthy controls, matched for age and sex (14 men, 17 women, mean age 41.5, SD 10.6, range 22.2-61.8) participated in the study. The subjects were scanned with a Philips Ingenia 3.0 T (Philips Health Care, Best, The Netherlands) using a 3D gradient echo sequence with out-of-phase and in-phase echo times of 3.66 ms and 7.24 ms respectively. The repetition time was 10 ms, the flip angle was 10 degrees. The acquisition time was 9.07 minutes and the images covered C2 down to Th1 with a resolution of 0.75*0.75*0.75 mm^3. Phase sensitive reconstruction of the data was performed[2,3] and the cross-sectional area was segmented at the C4, C5, C6 and C7 levels using Analyze 11 (AnalyzeDirect, USA). The cross-sectional area and the proton density fat fraction[4] were calculated using MATLAB2013b (Mathworks Inc., USA). In the analysis the WAD group was divided in those with mild/ moderate disability ($\leq$ 40%) on the Neck Disability Index (NDI) and those with severe disability (NDI > 40%). ANOVA with Bonferroni post-hoc test was performed with significance level $p < 0.05$. Statistical analysis was performed in SPSS19 (IBM, USA)
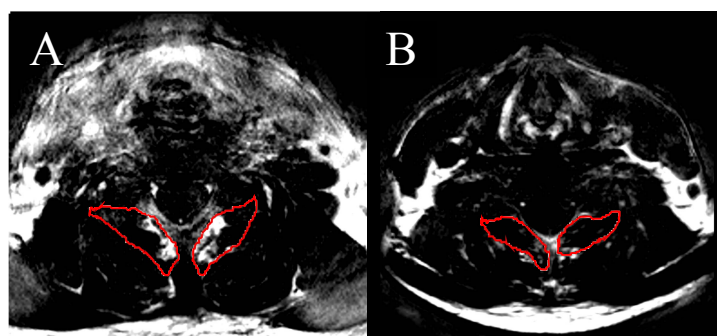

Fig. 1: Cross-section at C6-level of the multifidus muscle marked on a patient with severe WAD disability (A) and on its age and gender matched control (B).

Results: Individuals with severe disability had significantly (p=0.03 to 0.04) higher content of fatty infiltration on the right side of multifidus of the neck (C4 to C7 averaged) compared to healthy controls as well as those with mild/ moderate WAD disability and those individuals with severe WAD disability also had higher total fatty infiltration in multifidus (left and right averaged) compared with those with mild/ moderate disability (p=0.03). When fatty infiltration in a single segmental level, see Fig. 1, was compared between groups, those with severe WAD disability had significantly higher fatty infiltration than the other two groups in multifidus C4 right side (p=0.007 and p=0.04 respectively), C6 right side (p=0.03) compared to healthy controls and C4 left side (p=0.02) compared with the mild/ moderate WAD group. There were no significant differences between those with mild/ moderate disability and healthy controls. No significant differences was observed among any of the groups regarding the cross-sectional area, see Table 1.

	n	Mean area ± standard deviation [mm^2]			Mean PDFF ± standard deviation		
		Left	Right	Average	Left	Right	Average
HC	31	298.59±71.51	291.19±68.14	294.89±68.29	0.11±0.08	0.11±0.08	0.11±0.08
NDI≤40	21	285.93±54.99	279.73±64.14	282.83±57.96	0.10±0.07	0.10±0.08	0.10±0.07
NDI>40	10	339.51±80.52	316.72±88.38	328.11±83.30	0.18±0.11	0.19±0.09*†	0.18±0.10†

Table 1: Significant differences (p < 0.05) between patients with severe disability (NDI>40) compared to healthy controls and patients with mild/moderate disability are marked with * and † respectively. PDFF = proton density fat fraction.

Discussion: The findings of higher fat infiltration in patients with severe WAD compared to healthy controls and patients with mild/moderate validate higher fat infiltration reported in previous findings[1]. The morphological changes of the muscle in patients with severe disorders confirm the need for further analyzes of the content in the muscle and not only the volume or area[5]. Therefore, MRI methods, which also can separate the pure muscle tissue apart from the intra-muscular fat, are of high interest.

Conclusion: Individuals with severe neck disability after a whiplash injury had a higher fatty infiltration in the multifidus muscle, both compared to neck-healthy controls and to those with mild/ moderate disability. Furthermore, earlier reported findings using T1-weighted MRI was reproduced also using fat and water separated MRI. The present study verifies earlier reports of morphometric changes in the multifidus muscle for those with remaining severe disability after a whiplash injury. These findings may be useful when developing better and objective diagnostic tools for diagnosis and classification with WAD, based on water-fat separated MRI.

References: [1]Elliott J et. al. Fatty infiltration in the cervical extensor muscles in persistent whiplash-associated disorders. Spine 2006;31:E847-55. [2]Rydell J et. al. Three dimensional phase sensitive reconstruction for water/fat separation in MR imaging using inverse gradient. International Society for Magnetic Resonance in Medicine (ISMRM). Toronto, Canada 2008. [3]Rydell J et al. Phase sensitive reconstruction for water/fat separation in MR imaging using inverse gradient. International Conference on Medical Image Computing and Computer-Assisted Intervention (MICCAI). Brisbane, Australia 2007. [4]Reeder SB. et. al. Iterative decomposition of water and fat with echo asymmetry and least-squares estimation (IDEAL): application with fast spin-echo imaging. Magnetic resonance in medicine : official journal of the Society of Magnetic Resonance in Medicine / Society of Magnetic Resonance in Medicine 2005;54(3):636-644. [5]Elliott JM. et. al. Content not quantity is a better measure of muscle degeneration in whiplash. Man Ther 2013;18:578-82.