Functional T_2 Measurements in Lower Back Muscles Before and After Isometric Muscle Contraction

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Target audience Researchers in MR physics and muscle physiology

Purpose Recently, functional transverse relaxation MR imaging has been proposed to assess muscle fatigue and/or to investigate pathological changes in muscle diseases [1-3]. MR imaging of lower back muscles requires fast (single-shot) sequences to overcome problems caused by motion. However, the commonly used (multi-echo) turbo-spin-echo sequences (TSE) may produce erroneously increased T_2 values due to signal contaminations of stimulated echo components caused by B_1 inhomogeneities. This limitation can be avoided by applying B_1-insensitive spin-echo echo planar (SE-EPI) acquisitions (Fig. 1) [3]. The aim of this work was to evaluate the feasibility of applying SE-EPI in lower back muscles to determine T_2 relaxation changes in lower back muscles during exercise in a group of healthy male volunteers.

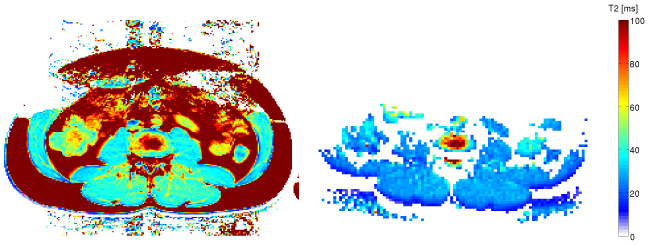

Fig. 1 *T_2 map acquired with a TSE sequence (left) yields increased T_2 values compared to SE-EPI (right). In order to reduce image artefacts in SE-EPI (fat-shift in phase-enc. direction) fat suppression was applied.*

Methods The study included 14 healthy volunteers (male, 20-30 years old). All MR images were acquired in transverse orientation at the level of the intervertebral disk L3-L4 using a clinical 3 T whole-body MR scanner and a spine coil array (TIM Trio, Siemens Healthcare, Erlangen, Germany). A series of T_2-weighted images with incrementally increasing echo times (SE-EPI sequence, 3 slices, NEX = 6; FOV = 330 × 276 mm²; 3.0 × 3.0 mm²; d = 9 mm; TR = 500 ms; $TE_{1\text{-}5}$ = 32, 40, 48, 56, 64 ms; TA = 35 sec) was acquired pre- and post-exercise (1.5 min after end of load). Exercise was performed outside the scanner over a time period of 10 min and arranged as a modified Sørensen test [4] using a dedicated ergometer device, which provides an adjustable counterweight to support the subjects with 50 % of their upper body weight. Pre- and post-load T_2 weighted data were co-aligned by using a non-linear image registration method (www.picsl.upenn.edu/ANTS). T_2 maps were calculated with a custom-built MATLAB routine by pixel-wise mono-exponential fitting of the signal decays in the acquired series of T_2-weighted images. Additionally, ROIs were bi-laterally drawn in the inner (*M. multifidus*, MF) and outer (*M. erector spinae*, ES) regions of the lower back muscles on the T_2 weighted images and used for T_2 increase mapping and to determine the median T_2 relaxation times. Differences between median pre- and post-load T_2 values were tested with a two-sided sign test.

Results Tab. 1 lists the mean of the ROI-based median pre- and post-load T_2 values over all 14 subjects. Fig. 2 shows adjacent T_2 increase maps of a single subject, which reveal spatially varying T_2 changes in the ROIs. The values of ROI-based T_2 increases (in %) are illustrated in Fig. 3 for all subjects by colour-coded asterisks together with their boxplot distribution (including median, 25th and 75th percentiles).

Tab. 1 *T_2 values (mean ± SD) prior to and post exercise.*

ROI	mean T_2 ± SD prior to exercise [ms]	mean T_2 ± SD post exercise [ms]	*p*
left ES	26.8 ± 1.8	29.8 ± 2.9	.0018
left MF	27.0 ± 1.4	29.4 ± 3.0	.0129
right MF	27.1 ± 1.1	29.3 ± 2.6	.0129
right ES	27.3 ± 1.5	28.5 ± 2.1	.0129

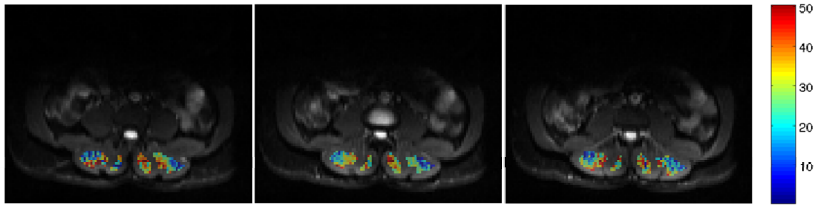

Fig. 2 *Transverse slices of a single subject with overlaid pixel-wise calculated T_2 increases (in ms), which yield an inhomogeneous spatial distribution within the examined ROIs. Highest T_2 changes were observed in the right MF.*

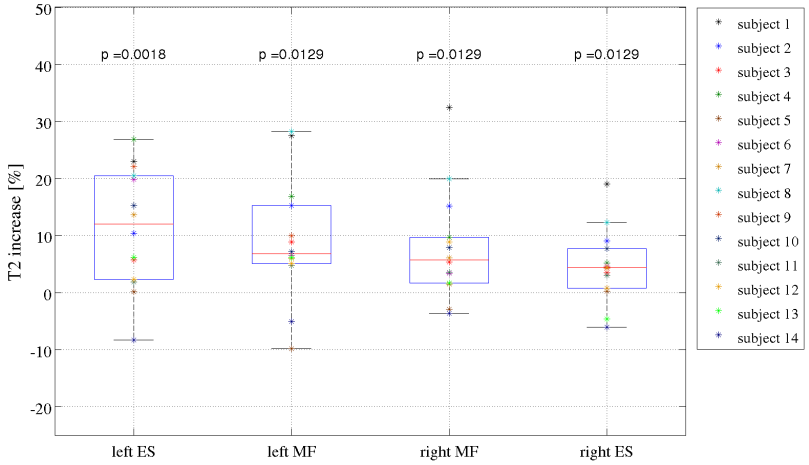

Fig. 3 *Boxplot of T_2 increases after exercise (in %) in the left and right lower back muscles (MF and ES) for 14 subjects.*

Discussion and Conclusion This work demonstrates the feasibility of functional quantitative T_2 mapping based on SE-EPI in the lower back muscles. Further improvements of spatial resolution might be achieved by using alternative sequence techniques, such as turbo-STEAM [5]. However, in all examined lower back muscles significantly increased T_2 values were observed, whereby the left muscles showed higher increases. Increased T_2 relaxation times are assigned to increases of intracellular muscle water content, which may occur due to intra-cellular metabolic accumulations. Therefore, combined measurements of functional T_2, ^{31}P-MRS and DWI measurements [6] may provide deeper insights in myo-cellular fatigue mechanisms in future.

References **1.** Louie EA. Magn Reson Med 2009;61(3):560-569. **2.** Tawara N. Magn Reson Med Sci 2011;10(2):85-91. **3.** Hiepe P. Proc ISMRM 20 (2012), #1860. **4.** Biering-Sørensen F. Spine 1984;9(2):106-19. **5.** Hiepe P. Z Med Phys 2011;21(3):216-27. **6.** Hiepe P. Proc ISMRM 19 (2011), #2013.