

Detectability of exercise-induced muscle activities of abdominal oblique muscle using muscle functional MRI

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Introduction

Measurement of exercise-induced muscle activity is essential in sports medicine and rehabilitation medicine. Strengthening of the trunk muscles (especially abdominal oblique muscle) is an integral part of rehabilitation programs for all athletes who must maintain stability during sport. Magnetic resonance imaging (MRI) can evaluate muscle activity; the transverse relaxation time (T₂) of exercised muscle is greater than that of rested muscle [1]. Therefore, evaluation of muscle activity using T₂-weighted MRI facilitates the identification of the most effective exercises for strengthening specific muscles. Akima *et al.* proposed the muscle functional magnetic resonance imaging (mfMRI) technique [2, 3] for visualization of muscle activity. However, for calculating T₂, the mfMRI uses the spin echo (SE) sequence, which requires an acquisition time of several minutes. This limits the utility of mfMRI to the limbs. In addition, although the spin-echo echo-planar-imaging (SE-EPI) sequence is useful for ultrafast imaging for calculating T₂ in regions such as the trunk, a limitation of SE-EPI is that the spatial resolution is extremely low. Therefore, in order to obtain image data for the T₂ measurement of small volume trunk muscles such as abdominal oblique muscle, both high spatial resolution and high temporal resolution are required. On the other hand, Welch *et al.* reported that T₂ estimation from double-echo-steady-state (DESS) sequence echoes, which provide both high temporal resolution and high spatial resolution, is useful for the assessment of cartilage morphology [4]. As a result of comparison of various muscle T₂ measurements in 3.0T-MRI, we suggest that it can be used as a measure of T₂ as well as DESS and SE, and also SE-EPI [5]. The purpose of this study was to evaluate visualization of the activation of abdominal oblique muscles induced by stretch exercise.

Methods

The right abdominal oblique muscles of five male subjects (25.8±7.4 years, 167.8±5.3 cm, and 63.4±9.4 kg) were scanned at rest and after exercise using a 3.0T whole body scanner (Magnetom Verio; SIEMENS AG, Erlangen, Germany) with a body matrix coil and a spine matrix coil. The protocols involved 3D-DESS [4] with TR 13.0 ms, TE 4.2 ms, voxel size 1.5×1.5×2 mm, matrix = 380×380, FA 45, BW 320 Hz/Px, field of view (FOV) 380 mm×380 mm, NEX 1, and acquisition time 25 seconds for 24 slices. The 3D-DESS sequence was SIEMENS's work-in-progress (W.I.P.). Subjects performed 5 sets of an exercise while standing (Figure 1). One exercise set consisted of the subject performing standing back rotation stretch exercises, to the right only, 100 times. From FISP images and PSIF images using constituent images of DESS, the T₂ images were calculated. Image processing involved Interactive Data Language (IDL; Exelis Visual Information Solutions, Boulder, CO, USA). Regions of interest (ROI) were placed in external and internal abdominal oblique muscles for the DESS's T₂-weighted images. Muscle T₂ was calculated from DESS images as described previously [4]. Visualization of muscle activity was carried out by DESS's T₂ mapping. T₂ of the right external and internal abdominal oblique muscles (ea; ex-abd-obl, in-abd-obl) was extracted from images obtained at rest and after various durations of exercise. Significance of differences between images obtained at rest and after exercise was determined by one-way repeated-measures ANOVA. Differences with P<0.05 were considered significant for each muscle.

Results and Discussion

Figure 2 shows DESS images at rest and after 5 sets. Although the DESS sequence has a temporal resolution as high as can be acquired under single breath-holding, these images have a high spatial resolution. In addition, in the DESS's T₂ images, the areas of activated right internal abdominal oblique muscle were well enhanced and morphological details were preserved. Figure 3 shows changes in T₂ after each set in each muscle. However, the value for the external abdominal oblique muscle was not increased by exercise, and there was no significant difference at rest. For all sets, the T₂ changes of the internal abdominal oblique muscle were significant compared with those at rest (P<0.01). Moreover, Figure 3 shows that the relationship of muscle T₂ with the workload was not linear. These results agree substantially with the signal intensity data of a previous study [6]. It was suggested that the T₂ of exercising muscle rises approximately exponentially to a plateau that depends on exercise volume.

Conclusion

In this study, we presented the detectability of trunk muscle activities. Detectability reached a plateau after exercise. T₂ values calculated from DESS images indicated high temporal resolution and high spatial resolution of muscle activities induced by acute exercise.

Acknowledgements

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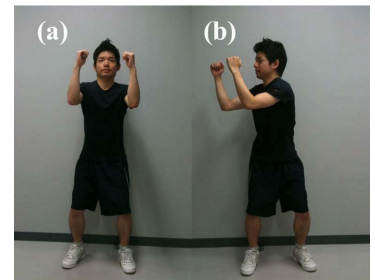


Figure 1: Standing back rotation stretch exercises of the trunk were repeated 100 times per set starting from a neutral position: (a) neutral position, (b) rotation position (only to the right).

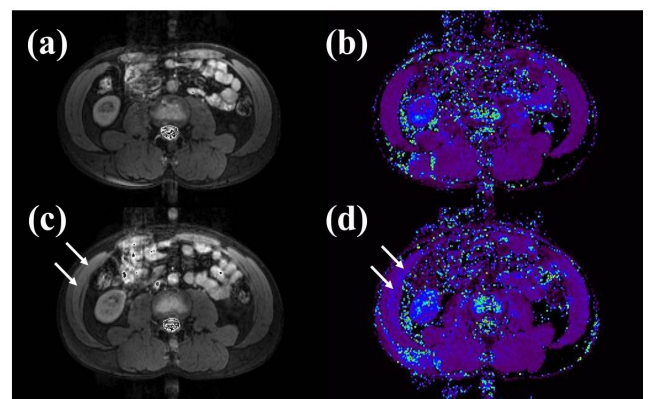


Figure 2: MR images of trunk at rest (in a, b) and after 5 sets of exercise (in c, d). (a, c) DESS's T₂-weighted images. (b, d) DESS's T₂ images. Arrows denote activated right internal abdominal oblique muscle. MR signal gain is constant in the images at rest and after exercise.

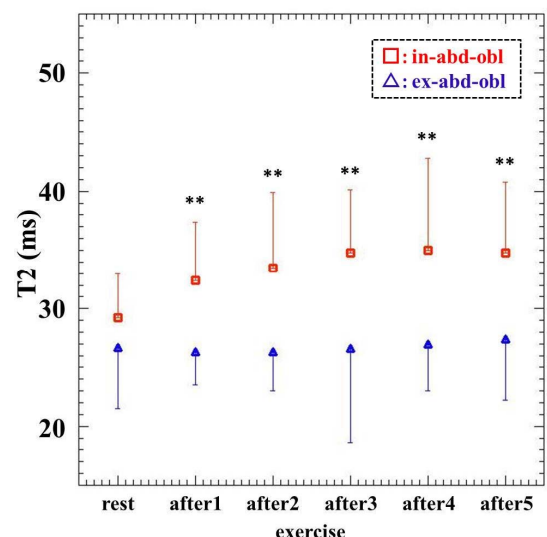


Figure 3: T₂ changes at rest and after exercise in five subjects. (Square) The right internal abdominal oblique muscle (in-abd-obl). (Triangle) The right external abdominal oblique muscle (ex-abd-obl). ** Significantly different from the value at rest, P<0.01.