Diffusion tensor imaging evaluation of upper leg muscular changes after long distance running

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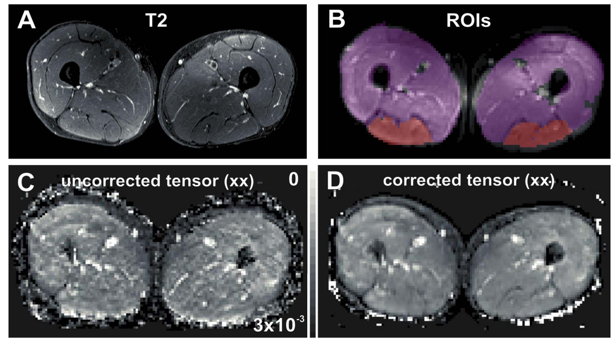
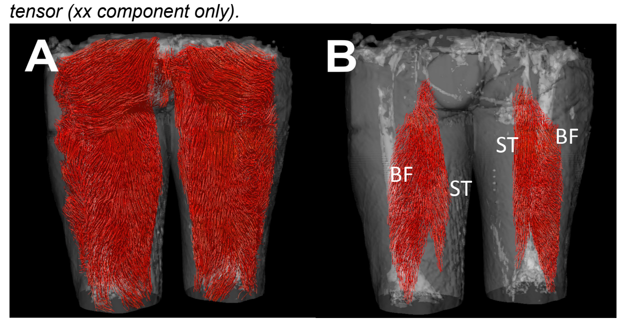
Introduction: Muscle overuse injury is among the most common injuries in sport and can lead to muscle strains. In muscle strains excessive tensile forces cause overstraining of the myofibers and rupture of the myotendinous junctions which leads to either intramuscular or intermuscular hematoma [1]. This pathology can be diagnosed using T2-weighed MRI. Muscle soreness after rigorous exercise is a very mild form of muscle injury with no clinical impairment. In this case only few muscle fibers are torn combined with minor swelling and discomfort which could lead to more severe forms if exercise is continued [1]. However, this very mild muscle damage cannot be evaluated using traditional techniques. Diffusion tensor imaging is a noninvasive technique that allows the quantification of the diffusion properties of water in anisotropic tissue in vivo. We hypothesize that diffusion perpendicular to the fiber direction will increase because of swelling or disruption of diffusion-hindering membranes. This could serve as an early indicator for exercise induced muscle injury. To investigate this hypothesis we acquired DTI data of 5 amateur long distance runners one week before, and 2 days and 3 weeks after they participated in a marathon.



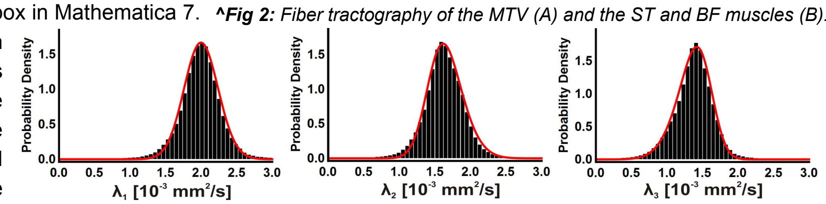
*^ **Fig 1:** A) T2 weighted image. B) non-weighted diffusion image with an overlay of the ROIs selecting the MTV and the BF and ST muscles. C) Uncorrected diffusion tensor (xx component only). D) Corrected diffusion tensor (xx component only).*

MRI: Both upper legs of 5 male healthy volunteers were measured using a 16 channel coil on a 3T Philips Intera scanner. Three acquisitions were performed: T2 weighted imaging to assess muscle damage, dual-echo gradient echo (GE) imaging to derive a B0-field inhomogeneity map and diffusion tensor imaging (DTI). The data was acquired in three 40 slice stacks with a 5 slice overlap and a FOV of 400x400 mm^2 and slice thickness of 4 mm. Total scan time was 45min. Further imaging parameters were; ***T2w:*** TSE, voxel size: 0.8x0.8 mm^2, TR/TE: 5500/70 ms, NSA: 2, ***GE:*** voxel size: 3.125x3.125 mm^2, TR/TE_1/TE_2: 12/4.6/9.6 ms, NSA: 1, ***DTI:*** SE-EPI, voxel size: 3.125x3.125 mm^2, 15 diffusion gradient directions, TR/TE: 7500/36 ms, NSA: 2, b=400 s/mm^2, fat suppression: SPAIR, SENSE factor: 1.4.



*^**Fig 2:** Fiber tractography of the MTV (A) and the ST and BF muscles (B).*

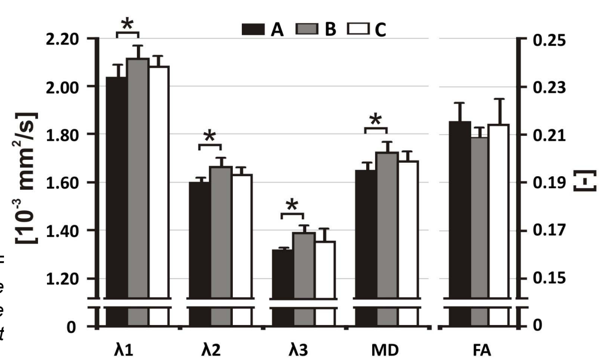
Analysis: The DTI data was processed using a custom build toolbox in Mathematica 7. First the data was filtered using a rician noise suppression algorithm [2] after which the diffusion weighted data was registered to the non-weighted images using an affine transformation and corresponding b-matrix rotation [3]. Next the diffusion tensor was calculated and corrected for field inhomogeneity induced deformations [4]. Finally the three individual stacks were joined together to create one large set. Using an automated tensor based masking algorithm a mask was created selecting only the muscle tissue volume (MTV). Based on the T2w images the biceps femoris (BF) and semitendinosis (ST) muscles were manually segmented in both the right and left leg. Mean diffusion parameters of the selected volumes were determined using a skew normal distribution. Data from the three different time points were compared using Wilcoxon signed-rank test (SPSS 17).



*^ **Fig 3:** Histograms of the eigenvalues for the MTV with the fitted skew normal distribution in red.*

Results and Discussion: Figure 1 A and B show a T2w image and the ROIs selecting the MTV and the ST and BF muscles respectively. The T2w images revealed no clinical impairment of the BF and ST. Fiber tractography of the selected volumes is depicted in figure 2. Figure 1 C and D depict the xx component from the diffusion tensor before (C) and after post processing (D). Figure 3 displays the histograms of the diffusion parameters for the MTV of one dataset together with the fitted skew normal distribution used to determine the mean. Mean values and the standard deviation of the tensor parameters for all the runners for each of the three time points are given in figure 4. There were no significant differences of the tensor parameters between the three time points for the WMV. For the ST and BF all eigenvalues and MD significantly increased two days after running (B) with respect to the week before (A). A month later the values were still slightly elevated with respect to time point A but not significantly different. FA changes were not significant in all cases. This could be due to the fact that the sample size was small and the FA typically has a larger variance than the other diffusion parameter. [5,6]

Conclusion: We have shown that rigorous muscle exercise by running increases the diffusivity of water in skeletal muscles that are known to suffer most, like the ST and BF [1]. Diffusivity increased both parallel as well as perpendicular to the muscle fibers. Higher values indicate that water diffusion is less restricted, which can be caused by swelling or the disruption of physical barriers like membranes or myofibers indicating muscle injury. The exact clinical correlation is still under investigation.



*> **Fig 4:** Diffusion tensor parameters for the BF and ST comparing the three time points: A one week before, B two days after and C three weeks after running a marathon. Significant differences (p<0.05) are indicated with a *.*

References:

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