The Effects of Effort on Running-Induced Changes in DTI and T_2 Mapping MRI Metrics in Lower Leg Muscles

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Summary

Quantitative MRI metrics can be used to evaluate muscle health and function in response to exercise. However, it is unknown how effort intensity impacts diffusivity and tissue hydration metrics extracted from diffusion tensor imaging (DTI) and T_2 mapping MRI. This knowledge is needed to understand if effort must be controlled in studies comparing patient and control groups, particularly when evaluating abnormal exertional conditions such as chronic compartment syndrome. Healthy participants ran for 10 minutes at 3 speeds and MRI metrics at baseline and temporally after exercise were evaluated across speeds to study the influence of effort on these metrics. The temporal behaviors of DTI and T_2 metrics were largely consistent across running speeds.

Introduction

DTI and T_2 mapping MRI provide valuable quantitative analyses of water diffusion and fluid content and can be used to study muscle microstructure, edema, hypertrophy, and perfusion as well as its response to exercise [1,2]. It is known that diffusivity and T_2 relaxation times increase with exercise [2], but the impact of exertional effort on these DTI and T_2 mapping metrics is unknown. We studied healthy subjects before and after running at three speeds to determine the influence of exertional effort on these metrics.

Methods

The subjects (n=2) received a bilateral baseline MRI scan of the lower leg muscles using DTI and T_2 mapping sequences, then performed 10-minutes of running at 6, 7.5, or 9 mph, followed by a second identical scan repeated 6 times for a temporal analysis (Fig. 1). Each consecutive scan began approximately 5 minutes apart. The subjects performed all 3 speed trials separately. Changes in mean diffusivity (MD), axial diffusivity (AD), radial diffusivity (RD), fractional anisotropy (FA), and mean T_2 relaxation time in response to exercise were compared across speeds. DTI metrics were calculated using a tensor fitting model in Diffusion Imaging in Python. T_2 times were calculated using a multi-spin-echo fitting method [3]. Temporal trends were compared using exponential decay fitting and coefficients of variation (CVs).

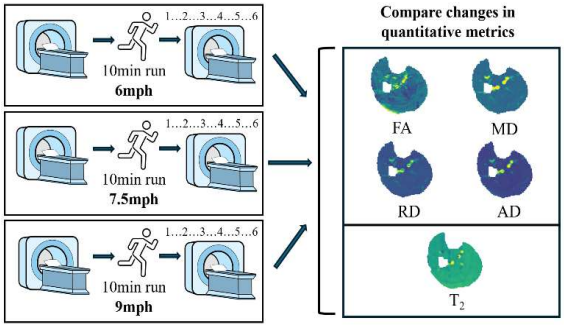

Figure 1: Changes in response to running for 10 minutes at 6, 7.5, and 9 mph were compared for DTI and T_2 mapping metrics in the lower leg muscles.

Results

T_2 relaxation times were elevated immediately after exercise and decreased over time for all speeds. An exponential decay curve was fitted to each of the three speed conditions, normalized to the final timepoint (Fig. 2). The starting values increased with running speed, but these differences across speeds fall within reproducibility limits of agreement from literature [4] and observed inter-subject variability. The decay rates were consistent across speeds (0.10, 0.09, and 0.10 $\frac{1}{min}$ for 6, 7.5, and 9 mph, respectively). DTI metrics did not vary between timepoints, thus did not follow an exponential decay model, and were consistent across timepoints and speeds. The CVs for MD, AD, and RD fell below 4% and the CVs for FA fell below 10%, which are comparable to reproducibility limits of agreement from literature [5].

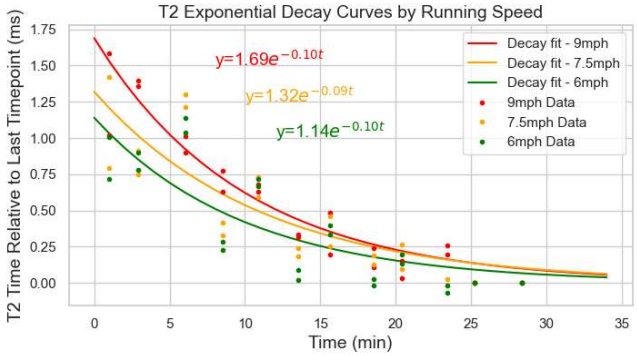

Figure 2: Exponential decay fittings of T_2 times across speeds.

Discussion & Conclusions

In this feasibility study with healthy subjects, running speed did not influence DTI metrics and T_2 relaxation times in muscle following exercise. We demonstrate that variations in intensity are unlikely to cause significant effects across subjects. Additionally, changes in DTI metrics in healthy subjects are negligible. These results suggest that (1) small differences in speed are unlikely to drive changes in these measures and (2) the small expected changes in healthy subjects offer more statistical power to detect abnormal trends in patient groups (e.g., chronic compartment syndrome) due to potential exercise induced pathologic changes.

Acknowledgments

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