BILATERAL SYMMETRY OF THE GASTROCNEMIUS STIFFNESS MEASURED WITH MAGNETIC RESONANCE ELASTOGRAPHY IN HEALTHY AND PATHOLOGIC MUSCLE

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INTRODUCTION

Quantifying the changes in skeletal muscle stiffness that occur with pathologies will improve our understanding of disease and injury and should lead to advances in treatment. Magnetic Resonance Elastography (MRE), a non-invasive phase contrast MRI technique, can visualize small displacements from applied shear waves and quantify the stiffness of soft tissues *in vivo* [1]. This technique has shown significant differences in the medial gastrocnemius muscle stiffness between the healthy volunteers and patients with spastic paraplegia, flaccid paraplegia and poliomyelitis, however, variations in the muscle stiffness in the left and right legs were observed in both populations [2]. Currently, we would like to use MRE to evaluate the effects of hemiplegic stroke and unilateral disuse atrophy on muscle stiffness by comparing the muscle stiffness in the affected limb to the unaffected limb. However, before this study can be conducted, it is necessary to determine a confidence interval to indicate if the differences are due to anatomic variations or if they are caused by pathology.

METHODS

Five healthy volunteers (4 female, 1 male, mean age: 26.4±3.3 years, BMI 21.3±2.0) were placed in a test jig with integrated MR compatible torque cells (Interface, Scottsdale, AZ). This jig fixed the ankle position in a range from 20˚ dorsiflexion (DF) to 40˚ plantarflexion (PF) in 10˚ increments. The loading was monitored with a custom LabView program (National Instruments, Austin, TX) including visual feedback to ensure that a constant load was applied by the subject. The volunteers' ankles were fixed at 10˚ of PF and they were asked to resisted isometric loads of 5-20 Nm in 5 Nm increments. MRE data were also collected with no contraction at 10˚ of DF, 10˚ of PF and 30˚ of PF in healthy volunteers and in one patient with hemiplegic stroke.

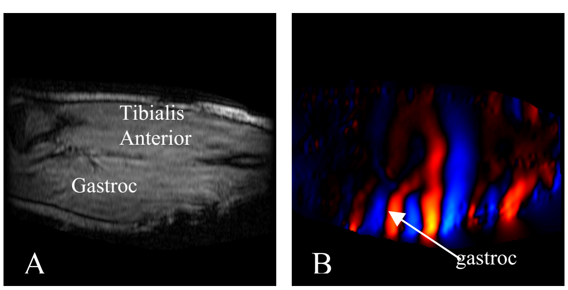

Fig 1. A) 2D MR image B) MRE image of gastroc

To collect MRE data, an electromechanical driver was strapped around the lower leg to induce shear waves into the gastroc at 100 Hz (f_e). A 2D 5 mm thick slice including the lateral gastroc was imaged with a gradient-echo, cyclic motion sensitizing sequence (TR/TE of 100ms/min full, 256x64 acquisition matrix, 24cm FOV) (Fig. 1). Each scan took 64 seconds to complete. The stiffness was calculated using a phase gradient technique after the data were smoothed with a directional filter. A 1D profile was drawn along the direction of the wave propagation in the complex first harmonic. The spatial frequency (f_s) was measured from the 1D profile and stiffness was defined as: $\mu = f_e^2 / f_s^2$.

Left to right symmetry was assessed using the Bland-Altman technique [3]. For each volunteer, the side-to-side difference in gastrocnemius stiffness was plotted against the mean stiffness. The confidence interval of anatomic variations was defined as the mean value of the difference in stiffness ± two standard deviations of the difference.

RESULTS AND DISCUSSION

The left to right difference and confidence interval ranged from -9.27 to 7.88 kPa. and -7.89 to 8.11 kPa, respectively in the Bland-Altman plot (Fig. 2). In the stroke patient, the difference between the gastroc stiffness in the affected and unaffected limbs was -3.45, 32.28 and 32.41 kPa when the ankles were fixed at 30˚ of PF, 10˚ of PF and 10˚ of DF, respectively. These differences exceeded the confidence interval in two of the three conditions tested, indicating a change in the muscle properties after a stroke.

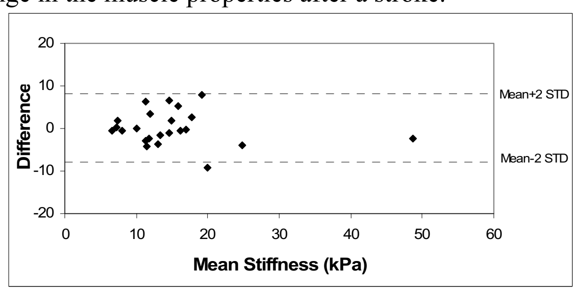

Fig. 2 Bland-Altman Plot of the left to right difference of gastrocnemius stiffness in five healthy volunteers.

CONCLUSIONS

A symmetry threshold was determined for the gastroc in PF loading and with no load at various ankle positions. While more data must be collected to include a more representative population, the preliminary results suggest that comparing the affected to unaffected limb when unilateral pathology is present will enable us to detect changes caused by injury or disease.

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ACKNOWLEDGEMENTS

This study is supported by NIH grants EB00812, EB01981, CA91959 and HD07447 We thank T.C. Hulshizer for his technical assistance.