

# MAGNETIC RESONANCE ELASTOGRAPHY: A NON-INVASIVE METHOD TO DIFFERENTIATE BETWEEN HEALTHY AND PATHOLOGIC MUSCLE STIFFNESS

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## INTRODUCTION

The underlying cause of functional changes that occur in skeletal muscle as a result of pathology or injury are often difficult to understand. Instead of measuring functional changes, quantification of the elastic properties of skeletal muscle may improve our understanding of the pathophysiology of muscular injury.

Magnetic Resonance Elastography (MRE) is a non-invasive phase contrast MR technique that can directly image induced shear waves in a muscle of interest. Tissue displacements caused by the shear waves are then calculated at each voxel and used to estimate the shear stiffness of the muscle (Manduca et al., 2001). The purpose of this project was to: 1) assess repeatability and reliability of MRE data analysis, 2) identify an asymmetry index in healthy asymptomatic volunteers and 3) to determine if MRE is capable of detecting differences between healthy and pathologic muscle.

## METHODS

Bilateral MRE data were collected from the lateral gastrocnemius in 11 asymptomatic volunteers (8 female, 3 male, age 25±3) and 10 patients (4 female, 6 male, age 54±20) with hemiparesis as the result of stroke.

Data were collected with the ankle positioned at 30° and 10° of plantarflexion, as well as 10° of dorsiflexion while the muscle was relaxed. Additionally, the ankle was positioned at 10° of plantarflexion while internal isometric dorsiflexion moments from 0-20 Nm were applied.

An electromechanical driver placed at the distal end of the gastrocnemius applied shear waves at 100 Hz. A gradient-echo, cyclic motion sensitizing sequence was used to obtain the MRE data (TR/TE of 100ms/min full, 256x64 acquisition matrix, 24cm FOV, acquisition time 68 seconds). Shear stiffness was estimated using a phase gradient technique (Manduca et al., 2001).

The data from the asymptomatic volunteers were used to assess repeatability (n=7), inter- and intra-operator reliability (n=5) of data analysis and an asymmetry index (n=11). The coefficient of repeatability was used to assess repeatability and reliability (Bland and Altman, 1995). The asymmetry index ( $A_x$ ) was calculated (equation 1), where D is the dominant limb and N is the non-dominant limb.

If  $D/N \geq 1$ , then  $A_x = D/N - 1$

If  $D/N < 1$ , then  $A_x = 1 - D/N$  (equation 1)

The asymmetry threshold was determined (equation 2), where  $t_{n-1, \alpha/2}$  was the critical value of a  $t$  distribution,  $n$  is the number of

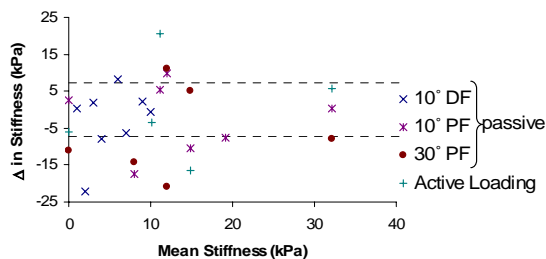
subjects, and  $s$  is the standard deviation of  $A_x$  (Kaufman et al., 1996).

$$A_{ul} = 0 \pm t_{n-1, \alpha/2} \frac{s}{\sqrt{n}} \quad (\text{equation 2})$$

The asymmetry threshold was used to determine if measured differences between the affected and unaffected limbs in the stroke patients were due to anatomic variations or because of changes in the mechanical properties of the muscle. A Wilcoxon signed rank test was used to compare the bilateral stroke patient data with bilateral age and gender matched healthy volunteers ( $n=3$ ).

## RESULTS AND DISCUSSION

The coefficient of repeatability was  $\pm 7.2$  kPa, the inter-operator reliability was  $\pm 3.55$  kPa and the intra-operator reliability was  $\pm 3.24$  kPa. The asymmetry threshold, indicating that differences in shear stiffness exceeding these limits are not due to anatomic variations, was  $\pm 7.3$  kPa. The asymmetry threshold was exceeded in at least one testing condition for all subjects with hemiparesis ( $10^\circ$  DF  $n=4$ ;  $10^\circ$  PF  $n=5$ ;  $30^\circ$  PF  $n=6$ ; active loading  $n=3$ ).

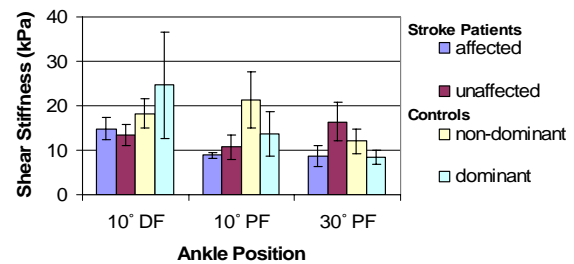


**Fig. 1.** Individual subject difference between affected and unaffected limb in stroke patients ( $n=10$ ). The dashed lines indicate the asymmetry threshold, which was exceeded in at least one testing condition for all subjects with hemiparesis ( $10^\circ$  DF  $n=4$ ;  $10^\circ$  PF  $n=5$ ;  $30^\circ$  PF  $n=6$ ; active loading  $n=3$ ).

Notable differences between the affected limb in the stroke patients and the non-dominant limb in the age matched normals

( $n=3$ ) were found when the ankle was positioned at  $30^\circ$  ( $p=0.07$ ) and  $10^\circ$  ( $p=0.1$ ) of plantarflexion (Fig. 2). Significance may be found with a larger sample size.

MRE is capable of detecting muscle pathology, both by comparing the affected to the unaffected limb in hemiplegic stroke patients as well as in comparison with age and gender matched control subjects. Strength testing and data collection from additional age matched neurologically intact subjects is planned to further interpret these data.



**Fig. 2.** Mean stiffness in hemiplegic stroke patients and age and gender matched control subjects ( $n=3$ ).

## SUMMARY AND CONCLUSIONS

MRE can detect differences in the shear stiffness between healthy and pathologic muscle. Further studies will be designed to interpret these differences.

## REFERENCES

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