

EFFECT OF AGE ON SHEAR MODULUS OF SKELTAL MUSCLE

Zachary J. Domire¹, Matthew B. McCullough¹ and Kai-Nan An¹

¹ Mayo Clinic College of Medicine, Rochester, MN, USA
E-mail: Domire.Zachary@mayo.edu

INTRODUCTION

With an increasing percentage of the population reaching old age, researching negative health consequences associated with aging has become increasingly important. Aging has many detrimental consequences in skeletal muscle. Because of resulting functional limitations, the bulk of research attention focuses on the progressive loss of muscle strength accompanying aging. However, changes in passive structures within muscle may also have negative health effects.

It is known that during aging advanced glycation endproducts result in cross-linking of collagen fibers in tissues throughout the body (Avery and Bailey, 2005). These cross-links result in increased tissue stiffness. Negative effects of this stiffening have been seen in numerous tissues, including cardiac muscle (Asif et al, 2000), bone (Vashishth et al, 2001), and articular cartilage (Verzija et al, 2000). Cross-links have also been shown to accumulate in the skeletal muscle of aged rats (Gosselin et al, 1998). Potential negative effects of this stiffening in muscle include decreased ability to remodel and increased risk for injury.

Magnetic Resonance Elastography (MRE) is a novel imaging technique that allows measurement of tissue shear modulus in vivo (Muthupillai et al, 1995). In this technique a small amplitude shear wave is induced in a tissue. At the same time a motion-sensitizing gradient synchronized to the shear wave is applied. From this process

a phase shift can be measured using phase-contrast MRI. The displacement at each voxel can be directly calculated from this phase shift and the shear wave can be imaged as it moves through the tissue.

The purpose of the following study is to examine muscle stiffness changes associated with aging using MRE.

METHODS

20 female subjects were included in the study with an age range of 50-70 years. Scans were performed with the ankle in 20 degrees of plantarflexion. Vibration was applied by a small bar tapper to the distal end of the tibialis anterior muscle belly. The tapper was oriented parallel to the long axis of the leg and secured tightly in place with a Velcro band.

Strain modulus was calculated at each voxel by determining the phase gradient for a small window around each point. The magnitude of the shear modulus within the muscle was calculated as the mean value for each voxel within a central region of the muscle. The standard deviation of the moduli within this region was used as a measure of tissue homogeneity.

RESULTS AND DISCUSSION

There was not a significant relationship between age and shear modulus (Figure 1). However, several older subjects (over 65) had a much higher modulus than average. On the other hand, there was a significant relationship ($p < .05$) between age and the

standard deviation of the modulus (Figure 2). The R squared value for a linear fit to the data was 0.53.

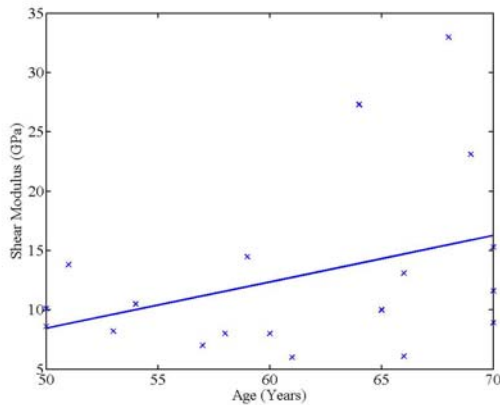


Figure 1: Shear Modulus vs. Age

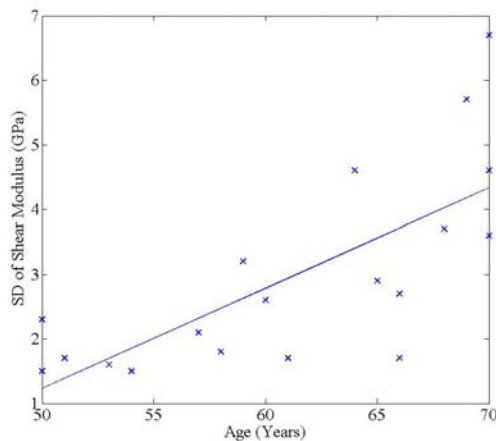


Figure 2: Standard Deviation of Shear Modulus vs. Age

The lack of a significant relationship between age and shear modulus is likely explained by the relatively narrow age range studied as well as the fact the other factors, such as physical activity, are likely to contribute to crosslinking (Gosselin et al, 1998). Given this however, the relationship between age and the standard deviation of the shear modulus is relatively strong. A less homogeneous muscle may be a result of age related crosslinking.

Identifying individuals with high concentrations of collagen crosslinking is important considering the negative health

consequences and that potential treatments exist. Exercise has been shown to significantly reduce collagen crosslinking in muscle (Gosselin et al, 1998). Though, the effects may be site specific (Thomas et al, 2001). A novel pharmaceutical crosslink breaker (Alt-711) is currently being tested and shows promise in treating stiffening of the cardiovascular system (Asif et al 2000) and may be useful elsewhere.

SUMMARY/CONCLUSIONS

Though there was not a significant relationship between age and shear modulus, all subjects with high values were amongst the oldest tested. The standard deviation of the modulus did increase with age indicating a less homogeneous tissue. More research is needed to determine if the changes seen here are reflective of increased tissue cross-linking. MRE shows promise as a tool to study development of cross-links or to evaluate treatments.

REFERENCES

- Asif, M. et al. (2000). *Proc Natl Acad Sci USA*, 97, 2809-13.
- Avery, N.C., Bailey, A.J. (2005). *Scand J Med Sci Sports*, 15, 231-40.
- Gosselin, L.E. et al. (1998). *J Appl Physiol*, 85, 1011-6.
- Muthupillai, R. et al. (1995). *Science*, 269, 1854-7.
- Thomas, D.P. et al. (2001). *Eur J Appl Physiol*, 85, 164-9.
- Vashishth, D. et al. (2001). *Bone*, 28, 195-201.
- Verzijl, N. et al. (2000). *Biochem J*, 350, 381-7.

ACKNOWLEDGEMENTS

This study was supported by a grant from the NIBIB R01 EB 00812