INTRODUCTION

Carpal tunnel syndrome (CTS) is a widespread peripheral neuropathy which occurs more frequently in women than in men [1]. While a great deal of research has been conducted, CTS etiology is not clearly understood. The transverse carpal ligament (TCL) makes up the volar border of the carpal tunnel. The TCL acts as a pulley for the flexor tendons running through the carpal tunnel, anchors the thenar and hypothenar muscles and is thought to play a role in the stability of the carpus. As a result of these important roles, the material properties of the TCL are of great interest. Recent studies of the TCL have shown its properties vary with location and depth due to the complex orientation of collagen fibers [2-5]. Brett et al., found that the TCL strains significantly more radially than ulnarly when under uniaxial load [2]. In addition, the study reported a trend that female specimens experienced more strain on the radial side of the TCL compared to male specimens [2]. Given the increased incidence of CTS in women, further work evaluating this trend, specifically a comparison of regional sex based differences in properties, is warranted.

Material properties derived from biaxial loading more closely reflect the in-vivo behavior of tissue. Based on the uneven loading of layers and difficulties in clamping thicker tissues, Sacks et al. [6] recommended that biaxial sample thickness should not exceed 3 mm with 1 mm being the optimal thickness to obtain valid results. As TCL thickness can approach 3 mm, biaxial testing of this ligament can become problematic. Histological and mechanical studies of the TCL have found that load bearing fibers in deep layers of the TCL become more organized, providing greater mechanical strength in comparison to superficial layers [4,5]. Testing only deep layers of the TCL would ensure that sample thickness approaches the recommended 1 mm and that the TCL fibers contributing to mechanical strength are evaluated.

The purpose of this study was to quantify deep TCL layer biaxial moduli to evaluate differences in between males and females, and radial and ulnar locations. The results of this work could impact our understanding of the etiology of carpal tunnel syndrome, and may improve treatment options, specifically related to non-surgical manipulative therapy.

METHODS

22 (13 Male (71±14.3 years) and 9 Female (81±2.8 years)) cadaveric wrists, were used in this experiment. Human ethics approval to conduct the study was obtained from the University of Toronto as well as the University of Guelph. Visual assessment of the tissue showed no discernible pathologies. Each wrist was dissected to expose the TCL. Two, 7 x 7 mm squares of the TCL were obtained from each specimen, centered through the proximal distal thickness and on either side of the medial lateral midline of the ligament. A layer of superficial tissue was removed from each sample. The final thickness was measured using a custom micrometer. Biaxial testing was performed using a CellScale BioTester (Waterloo, ON). Samples were mounted using four 5 mm rakes such that the predominant medial lateral fibers were aligned with the X axis. Samples were preconditioned over 10 cycles to 9% strain at 1%/s before undergoing biaxial strain to 12% at 1%/s. Axial forces and displacements were collected at a rate to 15 Hz. Cross sectional area was calculated based on tissue thickness and distance between rakes. Cross sectional area, force and rake displacement were used to determine stress-strain relationships for each
axis. The linear region of this plot was identified, and its slope was calculated to generate the elastic modulus. Statistical analyses were conducted using the GLM procedure in Minitab 17.1.0 (Minitab, State College, PA, USA) where specimen was included in the model as a random effect. Moduli were assessed by region (radial or ulnar), testing direction (medial-lateral or proximal-distal) and sex (male or female). When appropriate, differences were assessed using Tukey post-hoc analyses. In all analyses, \( p \leq 0.05 \) was required to declare a significant difference between means.

RESULTS AND DISCUSSION

The mean thickness of the tested samples was 1.14 ± 0.18 mm. Elastic moduli in the medial-lateral direction were significantly larger than the proximal-distal direction for both radial and ulnar samples (\( p=0.013 \)). Medial-lateral and proximal-distal elastic moduli of the ulnar samples were significantly larger than those of the radial samples (\( p=0.001 \)). No significant differences were found in elastic moduli between male and female specimens for any combination of region and/or direction (Figure 1).

This lack of significance suggests that the increased incidence rate of CTS in females may not be a result sex based differences in mechanical properties of the TCL. Significantly lower medial-lateral transverse elastic moduli for radial samples compared to ulnar samples support the findings of Brett et al. [2]. These results may be useful in improving manipulative therapy techniques used to treat CTS. The TCL may stretch more radially than ulnarly so manipulative therapy may benefit from focusing stretching on the radial side of the TCL.

This study is not without limitations, with an average specimen age of 81 in women and 71 in men, results may differ from results obtained from younger specimens. Sectioning the TCL does disrupt the fibers and may affect results, however, this effect would be consistent across all samples. Finally, while every effort was taken to keep the tissue moist during sectioning and testing, dehydration of the sample over the course of testing may have impacted results.

REFERENCES


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Figure 1: A – Comparison of mean biaxial elastic moduli in medial-lateral and proximal-distal directions between radial and ulnar TCL samples. Connected elements denoted by a star were found to be significantly different. B – Comparison of mean biaxial elastic moduli of radial and ulnar samples of the TCL in medial-lateral and proximal-distal directions between male and female specimens.