Gender Differences in Trapeziometacarpal Joint Space Changes with Axial Thumb Traction

Ricardo Ocampo[1], David Jordan[1], John Elfar[1], C. Kent Kwoh[3], Zong-Ming Li[1,2,3]
[1]Hand Research Laboratory, Departments of Orthopaedic Surgery, Tucson, Arizona; [2]Departments of Orthopaedic Surgery, Tucson, Arizona;
[3]Arthritis Center, University of Arizona, Tucson, Arizona
Email: lizongming@arizona.edu

Disclosures: Ocampo (N), Jordan (N), Elfar (N), Kwoh (N), Li (N)

INTRODUCTION: The trapeziometacarpal (TMC) joint is formed by the first metacarpal and trapezium. The joint enables a wide range of hand functionality, which can place the joint under complex loading conditions causing pathological disorders such as osteoarthritis (OA). There are gender disparities in the prevalence of OA as females have a higher incidence of TMC joint OA than males [1]. Physical examination can involve a variety of tests which include the application of forces to the thumb [2]. The biomechanical response of the TMC joint has been previously evaluated [3] and the response of the joint to such forces can be a potential indicator of the joint health. There may be gender differences in joint behavior among normal and structurally compromised joints.. Understanding the gender-specific behavior of the healthy TMC joint, when under the application of forces consistent with diagnostic assessment, can help establish baseline behavioral results which can be used for the comparative evaluation of structurally compromised joints. We compared the biomechanical response of the TMC joint under axial tensile load, between male and female cadaveric specimens without TMC OA. The hypothesis was that the change in CMC joint space with increasing tensile load would be greater for female compared to male specimens.

METHODS: Twelve cadaveric hand specimens with were prepared for testing (6 female, 69.5 ± 7.6 years; 6 male, 52.3 ± 6.6 years). The specimens were placed onto a custom platform, constraints were used to secure the forearm, the four fingers were secured around a cylindrical extension and the thumb was unrestrained. The specimens were placed into a CT machine and a finger trap was secured around the thumb. A wire was attached to the end of the finger trap and traversed over a custom-designed pulley system, with the thumb angled at approximately 45 degrees of extension (Figure 1a). A series of tensile loads (1N, 5N, 10N and 15N) were sequentially applied by attaching weights to the end of the pulley. A CT scan was taken for each applied load. Three-dimensional models of the CMC joint were generated from the CT scans for each loading condition. The articular surface of the first metacarpal was manually selected and the location of the saddle point was approximated [4]. A sphere of 2 mm radius was defined with center at the saddle point location. The intersection of the sphere with the articular surface defined a boundary, within which the minimum distance to the trapezium articular surface was calculated as the joint space (Figure 2). Mean and standard deviations of the joint space measurements were calculated for the male and female specimens for each load level. Linear regression and a comparison of slopes ($\alpha = 0.05$) was used to determine gender-specific differences in the biomechanical response.

RESULTS: The TMC joint space increased with the application of the axial tensile load (Figure 3). The mean TMC joint space at 1 N of axial load was 4.12 ± 0.74 mm and 3.11 ± 0.19 mm for the female and male specimens, respectively. With 15N of axial load, the mean joint space was 5.80 ± 0.70 mm and 3.73 ± 0.97 mm for the female and male specimens; indicating a maximum change in joint space of 1.68 mm for female specimens and 0.62 mm for male specimens. The slope of the linear regression line between the applied tensile load and TMC joint space was 0.111 mm/N for female specimens and 0.044 mm/N for male specimens, respectively. The Pearson correlation coefficients were $r = 0.923$ ($p = 0.077$) and $r = 0.973$ ($p = 0.027$). The magnitude of the linear regression slope for the applied tensile load and TMC joint space was larger for the female specimens than for the male specimens (0.067 mm/N; $p = 0.1164$).

DISCUSSION: The female specimens displayed a larger increase in TMC joint space than the male specimens for equivalent application of tensile loading. The gender-specific differences in joint space increase may be due to a variety of factors. The complexity of the TMC joint ligamentous and muscular anatomy requires that further studies be done to identify the fundamental reasons for the observed differences. It is known that certain pathologies of the TMC joint are more prevalent in females than in males and the observed biomechanical differences may provide insight into this phenomena. The results of this study help to initiate the establishment of normative biomechanical behavioral results in the TMC joint for males and females, which may then be used to quantitatively identify compromised joint behavior.

SIGNIFICANCE/CLINICAL RELEVANCE: These results examine the biomechanical behavior of the healthy TMC joint for males and females, serving as a potential comparative metric for future gender-specific anatomical and biomechanical evaluations of healthy and pathologically compromised TMC joints.

REFERENCES: [1] Oest et al., Osteoarthritis and Cartilage, 29, 2021. [2] Sela et al., J Hand Surg, 32(1), 2019. [3] Ikumi et al., Cureus, 14, 2022. [4] Halilaj et al., J Biomech, 46, 2013.

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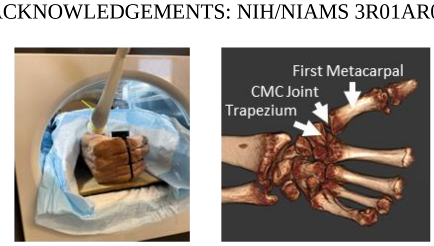

(a) (b)

Figure 1: Experimental set up. (a) Specimen in CT machine with finger trap attached to thumb. (b) Reconstructed three-dimensional skeletal anatomy.

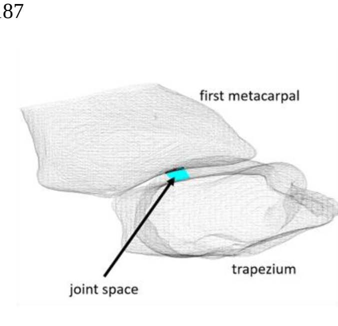

Figure 2: Representative example of the joint space calculation using the three-dimensional models of the first metacarpal and trapezium.

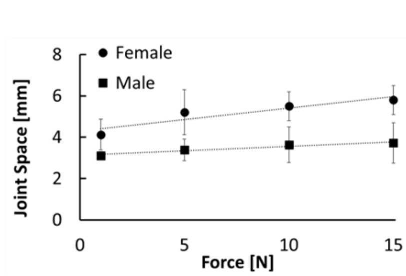

Figure 3: TMC joint space results with linear regression lines for male and female specimens at the applied axial tensile loads of 1N, 5N, 10N, and 15N.