Strength Ratio of Rotator Cuff Transverse Force Couple Is Not Associated with Glenohumeral Joint Contact Path Length in Individuals with Symptomatic Supraspinatus Tears

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INTRODUCTION: As the muscle group closest to the glenohumeral joint rotation center, the rotator cuff plays a crucial role in modulating joint mechanics. For example, the anterior (subscapularis) and posterior (infraspinatus and teres minor) rotator cuff muscles form a force couple in the transverse plane, exerting opposing forces on the humeral head.[1,2] Changes in the ratio of this force couple may affect humeral head displacement relative to the glenoid in the anterior–posterior direction. Understanding this potential relationship could provide insight into restoring altered joint mechanics in patients with shoulder injuries and offer clinicians a practical method for estimating joint function. Therefore, the purpose of this study was to investigate the relationship between the strength ratio of the transverse force couple and the anterior–posterior range of the glenohumeral joint contact path during scapular plane abduction, before and after exercise therapy, in male and female individuals with symptomatic rotator cuff tears isolated to the supraspinatus tendon. Males and females were studied separately due to sex-related differences in muscle strength. It was hypothesized that a non-monotonic relationship would exist in both sexes, before and after exercise therapy, with a balanced strength ratio associated with a minimized anterior–posterior contact path range.

METHODS: Sixty-three subjects (age 59 ± 9 years; BMI 27.6 ± 4.8 kg/m²) provided IRB-approved consent prior to participation in any research procedures. Each subject completed a 12-week personalized exercise therapy program designed for symptomatic supraspinatus tears and underwent isometric strength testing as well as in vivo glenohumeral joint motion capture before and after treatment. Isometric shoulder internal and external rotation strength was measured by a physical therapist using a hand-held dynamometer with subjects seated and their affected arm positioned at 0° humerothoracic abduction and 90° elbow flexion. Subscapularis strength was assessed during measurement of internal rotation strength, while the strength of the infraspinatus and teres minor was assessed during measurement of external rotation strength.[3,4,5] The strength ratio ([infraspinatus+teres minor]/subscapularis)*100% was calculated using the average strength value from three trials. Glenohumeral joint contact path during scapular plane abduction was obtained using biplane radiography and a previously validated model-based tracking technique (accuracy: ±0.4 mm).[6,7,8] The anterior–posterior range of the contact path was calculated from the trial (of three) that resulted in maximum abduction and normalized to glenoid width to account for inter-individual differences in bony morphology. Polynomial regressions were used to determine associations between the strength ratio and the anterior–posterior contact path range. Significance was set at $p < 0.05$.

RESULTS: After exercise therapy, both male (N = 31) and female (N = 32) subjects showed significant increases in infraspinatus and teres minor strength (males: $p < 0.001$ vs. females: $p < 0.001$) and subscapularis strength (males: $p = 0.031$ vs. females: $p = 0.002$) (Table 1). Compared with females, males were stronger by 71.4% (before therapy) and 71.6% (after) in infraspinatus and teres minor strength, and by 70.3% (before) and 65.7% (after) in subscapularis strength. For the anterior–posterior contact path range, males exhibited greater variability than females both before therapy (range: 5.5–34.4% vs. 3.7–22.3% of glenoid width) and after therapy (range: 3.1–37.8% vs. 3.2–19.3%). Polynomial regression results indicated no relationship between the strength ratio and the anterior–posterior contact path range in males ($p = 0.92$ before therapy vs. $p = 0.83$ after) or females ($p = 0.08$ before vs. $p = 0.18$ after) (Figure 1A, B).

DISCUSSION: The strength ratio of the transverse force couple was not associated with the anterior–posterior range of the glenohumeral joint contact path during scapular plane abduction in male and female individuals with symptomatic isolated supraspinatus tears, before and after exercise therapy. This finding does not support our hypothesis. A possible explanation is that this population retains an intact transverse force couple, functional deltoid and surrounding shoulder musculature, and intact static stabilizers. These structures maintain central compression of the humeral head within the glenoid, resulting in minimal displacement of the humeral head on the glenoid. Therefore, the impact of the strength ratio of the transverse force couple on the anterior–posterior contact path range is diminished, and no quantitative relationship is observed. This explanation can be supported by cadaveric studies showing that glenohumeral joints with only the supraspinatus tendon transected (preserved structural integrity of the transverse force couple) do not exhibit significant kinematic or kinetic alterations compared with shoulders with a fully intact rotator cuff.[9,10] Furthermore, the greater variability in anterior–posterior contact path range observed in males compared with females may be attributable to larger bone size and mass, which require greater compressive force to maintain humeral head centralization.[11] A limitation of this study was the potential influence of surrounding shoulder musculature on the accuracy of isometric strength measurements of the rotator cuff.[3,5] Future studies will determine the strength ratio of the transverse force couple using 3D muscle volume.

SIGNIFICANCE/CLINICAL RELEVANCE: Since no relationship was found between the strength ratio of the rotator cuff transverse force couple and the glenohumeral joint contact path length, the primary approach to restoring shoulder function and glenohumeral joint mechanics in both male and female individuals with symptomatic supraspinatus tears remains strengthening the shoulder girdle muscles, which is the current consensus for conservative treatment.

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ACKNOWLEDGEMENTS: Support from the National Institutes of Health grant 5R01AR069503 is gratefully acknowledged.

	Infraspinatus & Teres Minor Strength (kg)	Subscapularis Strength (kg)	Strength Ratio (%)	A-P Contact Path Range (% Glenoid Width)
Before Exercise Therapy				
Males	10.8 ± 3.2	15.5 ± 4.9	73.8 ± 21.7	16.5 ± 8.1
Females	6.3 ± 2.4	9.1 ± 3.0	71.1 ± 24.3	11.6 ± 5.2
After Exercise Therapy				
Males	12.7 ± 2.9	16.9 ± 3.7	76.9 ± 19.4	16.0 ± 8.5
Females	7.4 ± 2.7	10.2 ± 3.4	72.6 ± 14.6	11.1 ± 4.2

Table 1. Rotator cuff isometric strength and anterior–posterior glenohumeral joint contact path range data for male and female subjects before and after exercise therapy (Strength Ratio: [(infraspinatus+teres minor)/subscapularis]*100%).

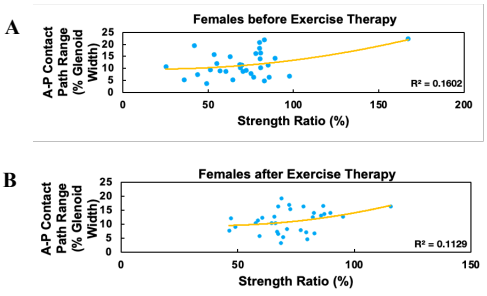

Figure 1. Relationship between the strength ratio of the transverse force couple and the anterior–posterior contact path range during scapular plane abduction in female subjects before (A) and after (B) exercise therapy.