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ORIGINAL RESEARCH

The Relationship Between Supraspinatus Tendon Moment Arm Length, Shoulder Anatomical Features, and Shoulder Disorders*

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ABSTRACT

This study aimed to evaluate the relationship between the moment arm length of the supraspinatus tendon and shoulder pathologies. The muscle-tendon moment arm represents the mechanical advantage of a muscle and significantly influences its role as a stabilizer or prime mover. In 83 patients, the presence of biceps tendinitis, rotator cuff tendinosis and tears, acromioclavicular joint degeneration, and footprint cysts were assessed. A perpendicular line was drawn from the center of the humeral head to the center of joint motion, and its length was measured (B). The distance from the rotator cuff footprint to the center of joint motion was also calculated (A). Subsequently, the ratio of these two lengths was determined (A/B). The mean moment arm length ratio (A/B) was 1.53 ± 0.11, the mean subacromial distance was 8.56 ± 1.35 mm, and the mean coracohumeral distance was 8.51 ± 1.51 mm. No significant correlation was identified between moment arm length and shoulder pathologies that could impact diagnosis, characterization, or treatment planning. A reduction in coracohumeral distance was associated with an increased incidence of tendinosis and tears in the subscapular tendon. Similarly, a decrease in subacromial distance correlated with a higher incidence of rotator cuff tears. Although moment arm length is important in surgical planning following tendon rupture, it does not serve as a diagnostic guide. The association between subacromial and coracohumeral distances and rotator cuff tendon tears may reflect a bidirectional relationship, where anatomical narrowing and tendon injury may influence each other.

Keywords*: Moment arm. Rotator cuff. Magnetic resonance.*

Supraspinatus Tendonunun Moment Kolu Uzunluğu ve Omuz Anatomik Özelliklerinin Omuz Patolojileri İle İlişkisi

ÖZET

Bu çalışmanın amacı; supraspinatus tendonunun moment kolu uzunluğu ile omuz patolojileri arasındaki ilişkiyi değerlendirmektir. Kas-tendon moment kolu, bir kasın mekanik avantajını temsil eder ve dengeleyici veya ana taşıyıcı olarak rolünü büyük ölçüde belirler. Bu çalışmada, omuz Manyetik Rezonans görüntüleme kaydı bulunan 83 hastanın biseps ile rotator manşet kaslarının tendinozis ve yırtıkları, akromiyoklavikular eklemde dejenerasyon, kemik kisti gibi patolojiler araştırıldı. Humerus başının en geniş olduğu kesitte başın merkezi işaretlenerek eklem hareket merkezine dik bir çizgi çizilmiş ve bu uzunluk (B) ölçülmüştür. Rotator manşet ayak izinin eklem hareket merkezine uzaklığı (A) hesaplanmış ve ardından bu iki uzunluğun oranı (A/B) belirlenmiştir. Ayrıca, akromiyon sınıflandırılmış ve subakromiyal ile korakohumeral mesafeler ölçülmüştür. Elde edilen sonuçlara göre, moment kolu uzunluğu oranının (A/B) ortalaması 1,53 ± 0,11, subakromiyal mesafe ortalaması 8,56 ± 1,35 mm ve korakohumeral mesafe ortalaması 8,51 ± 1,51 mm olarak hesaplanmıştır. Moment kolu uzunluğu ile omuz çevresi patolojileri arasında tanımlayıcı, tanı ve tedavi sürecini etkileyebilecek anlamlı bir ilişki tespit edilmemiştir. Bununla birlikte, Tip 2 ve Tip 3 akromiyonların, Tip 1'e kıyasla daha dar bir subakromiyal mesafe oluşturduğu görülmüştür.Korakohumeral mesafe azaldıkça subskapular tendonda tendinozis ve yırtık görülme sıklığının arttığı, subakromiyal mesafenin azalması ile rotator manşet yırtıklarının görülme sıklığının arttığı belirlenmiştir. Sonuç olarak moment kolu uzunluğu, rüptür sonrası cerrahi onarımda önemli bir faktör olmasına rağmen, tanı için yol göstericiliği yoktur . Subakromiyal ve korakohumeral mesafeler ile rotator manşet tendon yırtıkları arasındaki ilişki, anatomik daralma ile tendon hasarının birbirini karşılıklı olarak etkileyebileceği çift yönlü bir ilişkiyi yansıtıyor olabilir.

Anahtar Kelimeler*: Moment kolu. Rotator manşet. Manyetik rezonans.*

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Shoulder disorders are prevalent and frequently associated with trauma, sports activity, and aging[1]. Medical imaging technologies, including ultrasonography, X-rays, magnetic resonance imaging (MRI), and MR arthrography, provide valuable diagnostic information for formulating an effective treatment plan[2].

Biomechanical calculations yield information such as joint torque and muscle force, thereby facilitating a more comprehensive understanding of the circumstances under which mechanical overload of the musculoskeletal system can result in disorders[3]. The moment arm is defined as the perpendicular distance between the muscle-tendon line of action and the center of rotation of the joint from which the tendon originates. It plays a pivotal role in translating muscle force and linear displacement into joint torque and angular motion, thereby serving as a fundamental parameter in biomechanical analyses and musculoskeletal modeling[4]. The moment arm is defined as the mechanical advantage of a muscle and plays a crucial role in determining its function as either a stabilizer or a prime mover[5]. The geometric method and the tendon excursion method are widely employed for measuring the moment arm. The geometric method, which includes serial sectioning techniques such as X-ray and MRI, enables the direct measurement of muscle-tendon paths relative to joint centers[3,6].

Anatomical features, such as the acromion type and the subacromial and subcoracoid (coracohumeral) distances, have been associated with the etiology of shoulder disorders. For instance, Oh et al. emphasized the clinical importance of acromial spurs—particularly the heel-type—in the development of rotator cuff tears, suggesting that specific acromial morphologies increase mechanical impingement[7]. Similarly, Tan et al. used MRI analysis to demonstrate that variations in coracoid morphology and decreased coracohumeral distances are associated with subscapularis tendon pathology, indicating that anatomical narrowing may predispose patients to anterior impingement[8]. In surgical treatment, merely repairing the existing pathology without addressing the underlying anatomical factors contributing to the damage has often proven inadequate, frequently leading to the need for revision surgery. The literature includes studies that utilize measurements such as the critical shoulder angle, lateral acromial angle, and acromial index to predict these pathologies[9]. This study aimed to evaluate the correlation between the length of the supraspinatus tendon moment arm and shoulder pathologies, as well as the shoulder anatomical features previously examined in the existing literature. Furthermore, the roles of subacromial and coracohumeral distances in the development of shoulder disorders were also explored.

Material and Method

Ethical approval for the study was obtained from the Clinical Research Ethics Committee of Mersin University (approval number: 2023/729, dated 01.11.2023) prior to its initiation. Between January 2024 and May 2024, 83 shoulder MRI scans of patients who presented to our clinic and underwent MRI examination were reviewed using the digital archive system. Magnetic resonance imaging was performed using a 1.5 Tesla MR device (GE Signa, GE Healthcare Technologies, Chicago, Illinois). Images were acquired with the patients in the supine position using a standard shoulder coil. Axial PD FS, coronal T1 FSE , coronal PD FS, and sagittal PD FS sequences were used for all patients (TE 30 ms, TR 4500 ms, 4 mm slice thickness, 1 mm interslice gap, FOV 16 cm, 144x117 matrix). The images were examined to identify pathologies, including acromioclavicular joint degeneration, bone cysts around the rotator cuff footprint, and tendinopathies of the biceps, supraspinatus, infraspinatus, and subscapularis.

Subacromial and coracohumeral distance measurements, commonly investigated in the etiology of shoulder disorders, were conducted. The subacromial distance was measured using sagittal sequences, while axial sequences were employed for the measurement of the coracohumeral distance. **(**Figure 1**)**. Acromion morphology was classified according to the Bigliani system[10]. The measurement of supraspinatus moment arm length has been described through various methods in radiologic imaging literature; however, its association with shoulder disorders has not yet been established. In this study, a coronal PD FS was utilized to define the supraspinatus moment arm length. To account for anatomical variability among individuals, the moment arm length was expressed as a ratio (A/B), where "A" is the distance from the rotator cuff footprint to the joint center, and "B" is the radius of the humeral head. This approach minimized inter-individual anatomical variation and improved comparability across the study population. The ratio (A/B) of these two measurements was subsequently calculated **(**Figure 2**).** The relationship between the measurements obtained from MRI and the identified shoulder pathologies was investigated.

Statistical analysis of the obtained data was performed using SPSS (Statistical Package for the Social Sciences) version 22.0. For quantitative data, frequencies, percentages, means, and standard deviations were calculated. The chi-square test was used to assess differences in the frequency of categorical variables between groups. ANOVA and Kruskal-Wallis tests were applied to evaluate

differences in continuous variables such as age, subacromial distance, and coracohumeral distance among groups. For the analysis of differences between two groups, Mann-Whitney U and Student's t-tests were employed. Pearson correlation coefficient was calculated for correlation analyses. A p-value of less than 0.05 was considered statistically significant.

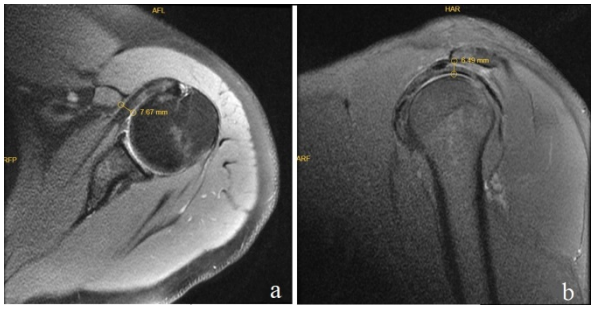

Figure 1:
a: *The technique for measuring the coracohumeral distance is employed in the axial PD FS section.* ***b****: The technique for measuring the subacromial distance is employed in the sagittal PD FS section.*

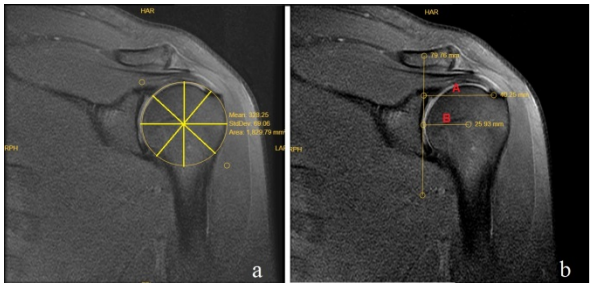

Figure 2:
a: *Finding the widest part of the humeral head in the coronal PD FS section and marking its center.* ***b****: The technique for measuring the moment arm length using the coronal PD FS section.*

Results

The study population comprised 46 females (55.4%) and 37 males (44.6%). Among the 83 shoulders examined, 47 (56.6%) were right shoulders, and 36 (43.4%) were left shoulders. The mean age was 57.5 ± 10.2 years (range: 45-91). Rotator cuff tears were present in 60 (72.3%) patients, with 11 (13.3%) having partial bursal tears, 22 (26.5%) partial articular tears, 15 (18.1%) small full-thickness tears, 7 (8.4%) medium full-thickness tears, 4 (4.8%) large full-thickness tears, and 1 (1.2%) massive full-thickness tear. Acromioclavicular degeneration was observed in 31 (37.3%) patients, and bone cysts around the rotator cuff footprint were found in 12 (14.5%) patients. Subscapularis tendinosis was identified in 38 (45.8%) patients, while subscapularis tears were seen in 7 (8.4%) patients.

The mean ratio of moment arm length (A/B) was calculated to be 1.53 ± 0.11, the mean subacromial distance was determined to be 8.56 ± 1.35 mm, and the mean coracohumeral distance was found to be 8.51 ± 1.51 mm. Subsequent to a thorough examination of the acromion morphology, the Bigliani classification system was employed to ascertain the acromion type. The findings revealed that 18 (21.7%) cases were classified as Type 1, 39 (47.0%) as Type 2, and 26 (31.3%) as Type 3 acromions.

The prevalence of acromioclavicular joint degeneration, bone cysts around the rotator cuff footprint, and rotator cuff tendon tears increased with age ($p < 0.05$). There was no association between age and rotator cuff tear size. No significant correlation was found between moment arm length and shoulder circumference pathologies that could impact the descriptive, diagnostic, and treatment processes. No association was observed between acromion morphology and rotator cuff tendinopathies. It was found that Type 2 and Type 3 acromions create a narrower subacromial space compared to Type 1 ($p < 0.05$). A positive correlation was identified between the subacromial space and the coracohumeral distance. It was observed that as the coracohumeral distance decreased, the frequency of tendinosis and tears in the subscapularis tendon increased ($p < 0.05$). Additionally, a reduction in the subacromial space was significantly associated with increased frequency of rotator cuff tears ($p < 0.05$). No significant effect of gender on the observed pathologies was found.

Discussion and Conclusion

The objective of this study is to investigate the biomechanical and anatomical determinants that contribute to the development of shoulder pathologies, with a specific emphasis on the interplay between moment arm length, subacromial distance, coracohumeral distance, and their association with various shoulder disorders. No statistically significant association was observed between supraspinatus tendon moment arm length and the presence of shoulder pathologies in a manner that would influence diagnostic interpretation, clinical characterization, or therapeutic planning. In contrast, a reduction in coracohumeral distance demonstrated a notable correlation with increased frequency of subscapularis tendinopathy and partial or full-thickness tears. Likewise, narrowing of the subacromial space was found to be positively associated with a higher prevalence of rotator cuff tendon tears.

The lack of a significant correlation between moment arm length and shoulder circumference pathologies

suggests that moment arm length may not be a critical determinant in the onset or progression of these pathologies. Previous studies investigating moment arm length have employed both cadaveric and imaging-based models, each with distinct advantages and limitations. For example, Ackland et al. and Pandy emphasized the anatomical variability and mechanical significance of moment arms in cadaveric simulations, while Zhang et al. demonstrated substantial interindividual variation in vivo using 3D MRI models, but found no significant correlation between moment arm length and pathological outcomes[5,6,11]. Similarly, Hughes et al. showed comparable moment arm lengths across techniques, underscoring methodological reliability[12]. In contrast, Leschinger et al.'s simulation highlighted the clinical importance of moment arm shortening after supraspinatus medialization[13]. Collectively, these mixed findings suggest that while moment arm length is biomechanically relevant, it may not independently predict shoulder pathology on imaging. Our study aligns with this view, as we also did not observe a significant association between the moment arm ratio and structural pathologies.

A study investigating the risk factors for partial rotator cuff tears using MRI identified several key factors, including age, subacromial distance, coracohumeral distance, and abnormal acromioclavicular signals. These findings are consistent with the results of our study, where similar risk factors were observed[14]. With advancing age, we observed an increase in the presence of degeneration in the acromioclavicular joint, the formation of bone cysts around the rotator cuff footprint, and the frequency of rotator cuff tendon tears. However, in our study, no relationship was found between acromion morphology and rotator cuff tendinopathies. Conversely, a comprehensive review on acromion morphology has identified a significant association between Type 3 acromion and rotator cuff tears[15].

Furthermore, we observed that a reduction in subacromial distance was associated with an increased frequency of rotator cuff tears; however, a cutoff value could not be determined. It has been reported that a reduced subacromial distance is associated with both rotator cuff tears and fatty degeneration[16]. Goutallier et al. have associated a subacromial distance of less than 6 mm with full-thickness rotator cuff tears[17]. A review of ultrasound studies has indicated that, in comparison to individuals who are healthy, those with rotator cuff injuries exhibit a reduced subacromial distance[18].

We found that the incidence of tendinosis and tears in the subscapularis tendon increased as the coracohumeral distance decreased. However, Tan et al. reported in their study using MRI and computed tomography (CT) that coracohumeral distance had no significant effect on subscapularis tendinopathies[8]. Çetinkaya et al. found no significant difference in the coracohumeral distance between shoulders with surgically treated subscapularis tears and the healthy contralateral shoulders of the same patients[19]. Mi et al. have identified that coracoid coverage and the presence of cysts around the rotator cuff footprint may serve as predictors for subscapularis tendon tears[20]. However, in our study, no association was found between the presence of cysts around the rotator cuff footprint and rotator cuff tendon tears.

This study has several limitations that should be acknowledged. First, intra- and inter-observer reliability for MRI-based measurements (moment arm length, subacromial, and coracohumeral distances) was not assessed. Although all measurements were performed by a single experienced musculoskeletal radiologist to ensure consistency, the lack of reproducibility analysis limits the assessment of measurement reliability. Additionally, the study was conducted at a single institution using a cross-sectional design, which may limit the generalizability and causality inference of the results. Longitudinal and multicenter studies are warranted to validate and expand upon these findings.

The observed association between reduced subacromial and coracohumeral distances and rotator cuff tendon tears may suggest a bidirectional relationship. It is uncertain whether anatomical narrowing predisposes to tendon tears, or whether tendon degeneration and retraction result in apparent narrowing of these spaces. Further comprehensive and longitudinal studies are necessary to address this question.

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References

1. van der Heijden GJ. Shoulder disorders: a state-of-the-art review. Best Practice & Research Clinical Rheumatology. 1999;13(2):287-309.
2. Roy J-S, Braën C, Leblond J, et al. Diagnostic accuracy of ultrasonography, MRI and MR arthrography in the characterisation of rotator cuff disorders: a systematic review and meta-analysis. British journal of sports medicine. 2015;49(20):1316-1328.
3. Juul-Kristensen B, Bojsen-Møller F, Finsen L, et al. Muscle sizes and moment arms of rotator cuff muscles determined by magnetic resonance imaging. Cells Tissues Organs. 2000;167(2-3):214-222.
4. Maganaris CN. Imaging-based estimates of moment arm length in intact human muscle-tendons. European journal of applied physiology. 2004;91:130-139.
5. Ackland DC, Pak P, Richardson M, et al. Moment arms of the muscles crossing the anatomical shoulder. Journal of anatomy. 2008;213(4):383-390.
6. Pandy MG. 4 Moment A rm of a Muscle Force. Exercise and sport sciences reviews. 1999;27(1):79-118.
7. Oh JH, Kim JY, Lee HK, et al. Classification and clinical significance of acromial spur in rotator cuff tear: heel-type spur and rotator cuff tear. Clinical Orthopaedics and Related Research®. 2010;468(6):1542-1550.
8. Tan V, Moore Jr RS, Omarini L, et al. Magnetic resonance imaging analysis of coracoid morphology and its relation to rotator cuff tears. American journal of orthopedics (Belle Mead, NJ). 2002;31(6):329-333.
9. Heuberer PR, Plachel F, Willinger L, et al. Critical shoulder angle combined with age predict five shoulder pathologies: a retrospective analysis of 1000 cases. BMC musculoskeletal disorders. 2017;18:1-9.
10. Lu B. The morphology of the acromion and its relationship to rotator cuff tear. Orthop Trans. 1986;10:228.
11. Zhang Y, Herbert RD, Bilston LE, et al. Three-dimensional architecture and moment arms of human rotator cuff muscles in vivo: Interindividual, intermuscular, and intramuscular variations. Journal of Anatomy. 2024.
12. Hughes RE, Niebur G, Liu J, et al. Comparison of two methods for computing abduction moment arms of the rotator cuff. Journal of biomechanics. 1997;31(2):157-160.
13. Leschinger T, Birgel S, Hackl M, et al. A musculoskeletal shoulder simulation of moment arms and joint reaction forces after medialization of the supraspinatus footprint in rotator cuff repair. Computer Methods in Biomechanics and Biomedical Engineering. 2019;22(6):595-604.
14. Wu H, Zuo Z, Li Y, et al. Anatomic characteristics of shoulder based on MRI accurately predict incomplete rotator cuff injuries in patients: relevance for predictive, preventive, and personalized healthcare strategies. EPMA J 2023:553-570.
15. Yadav SK, Zhu WH. A systematic review: Of acromion types and its effect on degenerative rotator cuff tear. International Journal of Orthopaedics. 2017;3(1):453-458.
16. Saupe N, Pfirrmann CW, Schmid MR, et al. Association between rotator cuff abnormalities and reduced acromiohumeral distance. American Journal of Roentgenology. 2006;187(2):376-382.
17. Goutallier D, Le Guilloux P, Postel J-M, et al. Acromio humeral distance less than six millimeter: its meaning in full-thickness rotator cuff tear. Orthopaedics & Traumatology: Surgery & Research. 2011;97(3):246-251.
18. Seitz AL, Michener LA. Ultrasonographic measures of subacromial space in patients with rotator cuff disease: a systematic review. Journal of clinical ultrasound. 2011;39(3):146-154.
19. Çetinkaya M, Kaptan AY, Ulucaköy C, et al. Is it the subcoracoid impingement or the subacromial impingement that tears the subscapularis tendon? A comparison of the MRI findings of the operated and healthy shoulders of the patients. Turk J Med Sci. 2023;53(1):273-281.
20. Mi Y, Lin Y, Cheng B. Magnetic resonance imaging based coracoid process morphology and its associations with isolated subscapularis tendon tears in Chinese patients. Jt Dis Relat Surg. 2024;35(2):267-275.