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Shoulder and elbow pathology in the female athlete: sex-specific considerations

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Unique biologic and biomechanical aspects of the female body make women more prone to certain orthopedic injuries. Sex differences are well understood with regard to certain orthopedic pathologies such as anterior cruciate ligament injury, hallux valgus, carpal tunnel, and carpometacarpal joint arthritis; however, sex differences are less commonly discussed with regard to shoulder and elbow pathology. The purpose of this review is to elucidate sex differences specific to sports-related shoulder and elbow injuries in the female athlete population.
Level of evidence: Narrative Review.

Keywords: Shoulder pathology; elbow pathology; female athlete triad; sex differences; generalized joint laxity; female athlete

Sex differences are critical in the treatment of orthopaedic conditions.[51] Notably, epidemiologic studies demonstrate higher rates of injury among female athletes. Following the inception of Title IX in 1972, female participation in US athletics has increased and is currently is at an all-time high.[38,40] Further, female athletes demonstrate both higher incidences of overuse injuries, concussion and stress fractures.[23] Schroeder et al[62] described the epidemiology overuse injuries in high school athletes, reporting an overall overuse injury exposure rate of 1.5 per 10,000 athletic exposures. The authors found that female athletes demonstrated greater rates of overuse injuries compared with male athletes (1.88 vs. 1.26), with the highest rates of injuries among female track and field and field hockey athletes.[62] Given the rapid rise in female sports participation and injury, it is critical that physician recognize sex-specific pathology affecting the female athlete.

Systemic considerations

Generalized joint laxity

Underlying many specific female, sport-related pathologies is an increased propensity toward generalized joint laxity (GJL). GJL is also known as systemic joint laxity, which is a condition characterized by synovial joint mobility beyond normal limits.[4,12,78] Studies have demonstrated that this condition is more pervasive among females and, specifically, identify postpubertal as the point at which the female preponderance becomes notable.[39,45] Some authors have attributed the differences to hormonal causes; however, the full complement of biologic factors coalescing to produce GJL is not yet fully understood.[27,66] Collagen composition is also an area of great research with Ehlers-Danlos

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syndrome (EDS) being a model of some of the most extreme manifestations of this condition.[69]

Notably, when considering connective tissue disorders such as EDS, sex plays an important role in the penetrance of conditions. The classic form of EDS demonstrates an autosomal dominant inheritance pattern.[11,42,69] However, research has noted an interplay between sex and the phenotypic presentation of this disorder.[42] Specifically, with regard to orthopedic manifestations, Castori et al[14] identified a sex influence on the manifestations of hypermobility-type EDS, presuming higher incidence among females than males. Knowledge of these associations is important for the orthopedic surgeon who assesses a patient presenting with joint laxity. Even in the absence of known family members with connective tissue disorders, a high index of suspicion for these conditions should be maintained and patients should be assessed for vascular disorders, scoliosis, and corneal abnormalities.

Given the predisposition of females toward GJL, an assessment of joint laxity is critical in the evaluation of any female athlete presenting with a sports injury. The Beighton score is a tool that can be used to help quantify GJL (Fig. 1) and has a maximum score of 9 points. Although thresholds vary in the literature, typically a score of 4 or 5 points or greater is considered consistent with joint hypermobility.[9,24,68] Knowledge of this condition may impact treatment decisions and outcomes, as increasing evidence has suggested that clinical outcomes may be impacted in patients with GJL.[58] Surgeons should counsel these patients accordingly to manage expectations.

Shoulder

Multidirectional instability

Multidirectional instability (MDI) is characterized as symptomatic subluxation or dislocation of the glenohumeral joint in at least 2 directions.[2,6,8,25,47,57] MDI was recognized as an entity different from unidirectional instability in 1980 by Neer, and the female bias toward MDI is well established.[8,16] Female athletes may be particularly susceptible to MDI because of an increased predisposition to joint hyperlaxity. In addition, female athletes tend to favor sports that both reward and demand flexibility such as gymnastics, ice skating, diving, yoga, and cheerleading, which may cause MDI to become more symptomatic.[63]

Patients with MDI commonly exhibit GJL. Studies have demonstrated that between 40% and 70% of patients with MDI meet the criteria for GJL.[57] Physical examination findings in patients with MDI may include the sulcus sign (Fig. 2), positive apprehension and relocation tests, and positive anterior and posterior load and shift tests. In addition, GJL is characterized by a high Beighton score.[9,24] In a cross-sectional cohort study of 1311 West Point cadets, Cameron et al[13] noted that when sex and race were controlled for, those patients with a Beighton score of ≥2 were nearly 2.5 times as likely (odds ratio [OR] = 2.48, 95% confidence interval = 1.19, 5.20, $P = .016$) to report a history of glenohumeral joint instability. This study demonstrates that even when controlling for the confounding variable of sex, the presence of GJL is an important consideration in patients presenting with MDI, as it may affect treatment outcomes, as has been demonstrated in both anterior cruciate ligament reconstruction and the modified Brostrom procedure.[28,80] As such, the combined variables of sex and GJL may affect patients in an additive fashion.

The cornerstone of treatment for patients with MDI is physical therapy. In a 2018 study, Watson et al[76] investigated the effects of conservative treatment of MDI in 43 patients. This study identified large treatment effects when comparing pre- and post-rehabilitation scores using the Melbourne Instability Shoulder Score, Western Ontario Shoulder Instability Index, and Oxford Shoulder Instability Score. This group also identified improvement in scapular motion and increased shoulder muscle strength in participants with MDI who performed a 12-week rehabilitation program. To gain better insight into the optimal therapy protocol, Warby et al[75] conducted a randomized control trial in order to establish the most efficacious rehabilitation protocol for patients with MDI. Their study of 41 participants concluded that 12 sessions of the Watson MDI program were more effective than the Rockwood program at 12- and 24-week follow-up.[75] When these options fail, surgeons may need to consider progression to operative management, which may include capsulorrhaphy. The decision with regard to operative technique is highly dependent on patient history and physical examination, occupation, and athletic/recreational demands as well as compliance.

When nonoperative management fails, surgical stabilization may be required, and it is important for surgeons to understand the differences in surgical outcomes in female athletes. The Multicenter Orthopaedic Outcomes Network study group reported on sex-related differences in shoulder instability among 1010 patients and noted higher rates of capsular laxity in the female cohort compared with the male cohort, which demonstrated higher rates of labral pathology.[41] Similarly, in 2016, Raynor et al[54] reported on a total of 45 shoulders, 20 of which were female, after arthroscopic pancapsular capsulorrhaphy for MDI with a mean follow-up of 3.3 years. The authors noted that the female cohort was more likely to require rotator interval closure, which was performed in 58% of females in comparison with 5% of males. In addition, female patients demonstrated inferior American Shoulder and Elbow Surgeons scores as well as an increased rate of postoperative subluxations at 40% in comparison with 22%. In 2017, du

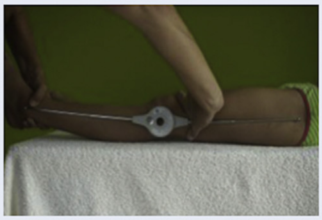
Maneuver	Example	Number of Points
Passive apposition of the thumb to the flexor side of the forearm, while shoulder is 90° flexed, forearm extended and hand pronated; score is positive if whole thumb touches flexor side of forearm		1 point for each side (maximum score of 2)
Passive dorsiflexion of the fifth metacarpophalangeal joint; score is positive if ≥ 90°		1 point for each side (maximum score of 2)
Passive hyperextension of the elbow; score is positive if ≥ 10°		1 point for each side (maximum score of 2)
Passive hyperextension of the knee; score is positive if ≥ 10°		1 point for each side (maximum score of 2)
Forward flexion of the trunk, with knees straight; score is positive if palms rest easily on the floor		1 point for the procedure (maximum score of 1)

Figure 1 Beighton score. Physical examination maneuvers, depictions, and instructions for calculating total points. Adapted with permission from Smits-Engelsman et al.[68]

Plessis et al[20] reported on 29 female patients who underwent a modified Latarjet for persistent shoulder instability and found that only 37.5% returned to sport, whereas reports across the general population range from 64% to 92%.[48,73] Thus, when considering surgical intervention for MDI, female athletes present a challenging population and

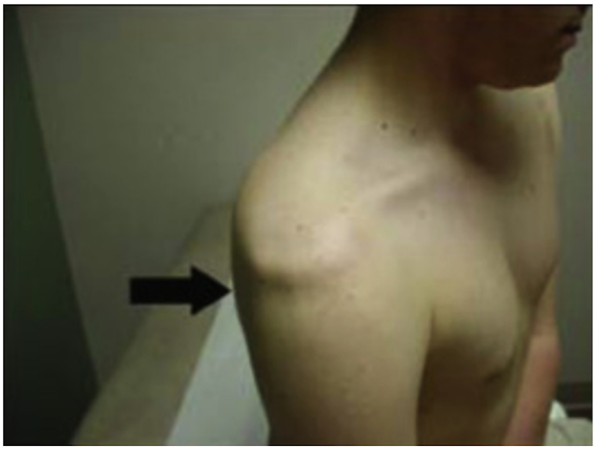


Figure 2 The "sulcus sign" (⟶) seen on physical examination demonstrating inferior capsular laxity in a patient with multidirectional shoulder instability. Adapted with permission from Apostolakos et al.[5]

one that is unique from their male counterparts. Attention should be paid to interval closure and tightening procedures, which may still result in higher rates of instability as compared with male patients.

Although MDI exists in both male and female cohorts, the etiology is different among these cohorts, being more related to capsular laxity in women in comparison with labral pathology in men. As athletes, women may be more prone to overuse syndromes and microtrauma, given their choice of sport participation, resulting in an increased risk of converting global laxity to symptomatic instability. A better understanding of both the optimal rehabilitation program for MDI and when nonoperative treatment fails is poorly understood and should be a subject of further research.

Rotator cuff pathology

Tendinopathies may affect men and women in different ways secondary to a combination of effects from sex hormones as well as inflammatory mediators.[29] In a 2020 case-control study in the *Journal of Orthopaedic Research*, the authors identified that distinct genetic factors play different roles in the development of the disease in males and females due to the interaction and function of diverse proteins in hormone-dependent pathways.[22] Specifically, the group noted that the dysregulation of matrix metalloproteinases (MMP2 and MMP3) has a greater impact on female risk for rotator cuff tear, whereas male disease was impacted more greatly by collagen haplotype. Other studies have shown the increased presence of matrix metalloproteinases in rotator cuff pathology along with inflammatory cytokines and cyclooxygenase enzymes, though these were not sex-specific.[72]

Although the sex-related bias in the rotator cuff disease prevalence is not clearly established in the literature, the authors have postulated that the aforementioned differences in inflammatory mediators and hormones modulate tendinopathies among females and may increase the prevalence of rotator cuff disease in female patients. In a cross-sectional study of 203 patients with symptomatic rotator cuff disease in comparison with 207 volunteer controls without cuff disease, da Rocha Motta et al[17] found that female sex carried a 2.07 increased OR for the development of rotator cuff disease. A study by Shim et al[65] demonstrated that rotator cuff tears were seen at increased rates in males less than 50 years old, whereas tears were more prevalent in females more than 50 years old. In contrast, Milgrom[44] failed to identify a correlation between sex and the presence of partial- or full-thickness rotator cuff tears in a study of 90 asymptomatic adults. Thus, a better understanding of specific discrepancies in symptomatology and age of onset between sexes might clarify differences in sex-based epidemiologic data regarding rotator cuff pathology.

Beyond incidence of tears, multiple studies have identified different surgical outcomes between males and females. In a 2009 cross-sectional study, Razmjou et al[55] demonstrated that women reported high interference in their social functioning compared with men after rotator cuff repair. In their study, women also reported higher levels of disability as defined by the Western Ontario Rotator Cuff index, American Shoulder and Elbow Surgeons, and QuickDASH scores.[55] Similarly, Daniels et al[18] demonstrated that women reported greater pain and decreased shoulder function compared with men during the initial 3 months after arthroscopic rotator cuff repair; however, they found that there was no difference in patient-reported outcomes at 1-year follow-up. Although these studies collectively suggest that female patients attain poorer outcomes after rotator cuff repair, little is published with regard to sex-specific outcomes with conservative management of such tears. Whether the aforementioned data suggest that women should be considered separately with regard to treatment algorithms, therapy protocols or counseling is not yet well established and further research is required to determine optimal treatment among females with rotator cuff disease.

Elbow

Distal biceps tendon rupture

Distal biceps tendon ruptures are common orthopedic injuries, but these injuries most frequently occur in men aged 40-60 years after an acute traumatic event.[32,52] In contrast, distal biceps ruptures in women are much less common. The majority of the literature describing distal biceps ruptures in females is limited to case reports or small case series.[7,21,32,46,50,70] A recent systematic review highlighted that of the 2253 subjects identified in 93 studies of distal biceps tendon ruptures, only 39 (1.7%) of the patients were women, and all of the studies that included women were published after 2000.[49] Other studies have cited similarly low proportions of females sustaining distal biceps tendon injuries, with 93%-98% of patients being male.[30,35,59,74] Although it is unclear why this drastic difference in incidence between sexes exists, it has been theorized that women may generate less force per cross-sectional area of the tendon than men, have inherent differences in the vascularity or tendon quality of the distal biceps, and may participate in fewer or less frequent activities that stress the distal biceps than men.[32,53,64]

Jockel et al[32] reviewed 15 cases of distal biceps tendon tears in 13 women. The mean age of the patients was 63 years (range, 48-79 years). Seven of the tears could be traced to a single injury, whereas the remaining 8 could not. Mean time from symptom onset to operative repair was 12.7 months. Thirteen of the 15 cases were partially attached, 1 was weakly attached, and only 1 was completely detached. Hinchey et al[30] also reported that partial distal biceps tendon ruptures were more common in women than in men ($P = .05$).

Overall, few studies have focused on female distal biceps ruptures to date. However, physicians should be mindful that female patients with distal biceps ruptures may be slightly older (late 40s to 70s), have a more insidious presentation, and be more likely to have partial tears as compared with their male counterparts.[30,32] Therefore, the pathophysiology of distal biceps tears in women is more likely due to a chronic, degenerative tendinopathy than the acute complete rupture commonly seen in men.[32] Given that women have been under-represented in the literature to date—and that a component of this may be time-dependent—future studies are necessary to better delineate the incidence, epidemiology, and outcomes of distal biceps tears in women.[49]

Osteochondritis dessicans of the elbow

Osteochondritis dessicans (OCD) of the elbow, a disorder involving the subchondral bone and cartilage, is most commonly found in skeletally immature athletes. Although the exact etiology is unknown, OCD is thought to be due in part to a combination of repetitive microtrauma and ischemia in young athletes playing sports that involve overhead throwing or high impact to the upper extremities.[34] Adolescent patients are most frequently affected. In a large epidemiologic study, Kessler et al[36] found that the age group most likely to have OCD lesions was patients aged 12-19 years, with an incidence of 3.4 cases per 100,000 patients.

Early reports of capitellar OCD initially cited prevalence in the dominant arm of Little League baseball pitchers; however, subsequently, cases of OCD lesions in the elbows of female gymnasts were reported.[31,67] In 1 consecutive case series of 116 patients with OCD lesions of the capitellum, 16 patients were females, all of whom were gymnasts.[34] Although gymnastics has been most commonly associated with female athletes with OCD of the elbow in the literature, other sports such as softball, soccer, and water polo have also been cited.[10,31,34,37,67,77,79] Overall, OCD of the elbow is still much more common in males than females, with early case series reporting that up to 98% of their cohorts with OCD of the elbow were male.[31] A recent study by Kessler et al[36] found a similar high predilection for males, as male patients had 6.8 times greater odds of having elbow OCD than females ($P <$ .0001).

Treatment options for OCD may include conservative management, elbow arthroscopy, or arthrotomy with drilling, curettage of the defect, removal of loose bodies, and/or radial shortening, which has been shown to significantly reduce mean force and contact area across the radiocapitellar joint in cadaveric studies.[19,31] Conservative management with activity modification can be attempted as a first step, but has had variable success.[31,67] Early initial attempt at surgical intervention also had modest success. Jackson et al[31] reported that only 1 of the 7 patients in their cases series was able to return and compete in gymnastics postoperatively. However, with recent advances in arthroscopy and surgical technique, more favorable outcomes have been reported in recent years. Jones et al[33] identified 21 consecutive patients who had undergone arthroscopic treatment for capitellum OCD lesions. They found that at a mean follow-up of 48 months postoperatively, the average rating using the Single Assessment Numerical Evaluation (SANE) score was 87% and 86% of patients were able to return to sport.[33] Seven of the 21 patients in the cohort were female.[33]

To date, the literature supports that OCD lesions of the elbow are more common in males than females, but adolescent females—particularly gymnasts—should be evaluated for OCD lesions if the clinical suspicion is high. Given the limited number of cases in the literature to date, further research is needed to better explore the most efficacious treatment options for females with elbow OCD, but surgical intervention has had some promising results in recent studies.

Posterolateral rotatory instability

Posterolateral rotatory instability (PLRI) is characterized by instability of the radiocapitellar and ulnohumeral joints and is typically caused by insufficiency of the lateral collateral ligament complex, and most commonly, the lateral ulnar collateral ligament (LUCL).[3,56] PLRI may arise as a result of an acute traumatic injury, from a chronic process resulting in LUCL attenuation, or from iatrogenic causes.

To our knowledge, no studies published to date have specifically investigated the sex differences in the incidence of PLRI between males and females, although patients undergoing surgical intervention for PLRI seem to be more often males than females. In a recent case series of 23 US military service members who underwent LUCL reconstruction between 2008 and 2013, 87% were men.[56]

In theory, patients with generalized ligamentous laxity, which is more common in females, may be at increased risk for PLRI.[43] However, an increased incidence of PLRI in females has not been reported in the literature. Although a difference in instability rates has not been previously demonstrated, 1 study of 51 normal, healthy volunteers found that women had significantly greater total elbow range of motion than men ($P = .01$) and specifically more flexion.[15] Hyperlaxity, defined as a Beighton score of 4 or greater, was also significantly correlated with elbow extension and overall range of motion, but the authors did not draw distinctions between sexes with respect to these variables.[15] In summary, although female patients may theoretically be at higher risk for developing acute or chronic PLRI due to their baseline increased ligamentous laxity, there is no current literature available to support this nor literature available with regard to sex-specific differential outcomes after treatment for this pathology. Until additional investigations can better describe the female-specific issues regarding the etiology PLRI, we cannot recommend for or against any sex-specific management considerations at this time.

Lateral elbow epicondylitis (tennis elbow)

Lateral elbow epicondylitis, also known as tennis elbow, is a common orthopedic condition affecting 1%-3% of adults annually.[60] Although many tennis players experience lateral epicondylitis at some point in their lifetimes, fewer than 10% of patients with lateral epicondylitis play tennis.[71] The pathophysiology of lateral epicondylitis classically stems from repetitive activities involving wrist extension and supination, which lead to microtrauma and degeneration of the extensor carpi radialis brevis tendon.[71] There is also likely a genetic component to lateral epicondylitis, as Hakim et al[26] found a heritability of 40% for tennis elbow in a study of monozygotic and dizygotic female twins. Other factors such as underlying anatomy, flexibility, patient age, vascularity, and tobacco use are also likely to contribute.[1,61]

Historically, men and women were considered to be affected equally by lateral epicondylitis.[71] However, Sanders et al[60] found that there was a slightly lower incidence of lateral epicondylitis in males than in females (3.3 per 1000 males vs. 3.5 per 1000 females). In a recent meta-analysis of factors associated with lateral epicondylitis, Sayampanathan et al[61] found that females had 1.29 higher odds of having lateral epicondylitis than males (OR, males:females 0.77; 95% confidence interval: 0.67-0.89, $P < .001$).

In addition, certain psychological factors may be associated with the development of tennis elbow. A recent study by Aben et al[1] compared men and women with lateral epicondylitis with healthy male and female controls to compare their psychological profiles and work place environments. The authors found that female patients with lateral epicondylitis reported lower levels of autonomy at work ($P = .002$) and doing more repetitive work ($P = .05$) than female controls.[1] All patients with tennis elbow (both men and women) had significantly higher scores on workload than healthy controls ($P = .03$).[1]

The management of lateral epicondylitis typically involves a trial of nonoperative management including activity modification, anti-inflammatories, bracing, physical therapy, and injections.[1] If conservative management is unsuccessful, surgical intervention can be considered. A recent epidemiologic, population-based study found that the proportion of cases of lateral epicondylitis treated surgically within 2 years of diagnosis tripled from 2002 to 2009 ($P < .0001$).[60] However, in general, conservative treatment options should be exhausted before offering surgical intervention, as the majority of patients will improve without surgery.[1]

In summary, although lateral epicondylitis is common in both men and women, recent evidence suggests that there may be a slightly higher incidence in women than in men. In addition to traditional risk factors such as age, activity level, mobility, and vascularity, recent evidence suggests that there may be genetic and psychological risk factors that may contribute to the development of tennis elbow as well. Notably, there is a lack of published literature with regard to differential treatment response to either conservative or surgical management of this pathology. Although conservative management is the first best step in the treatment of lateral epicondylitis for all patients, more research is necessary to determine if there are sex-specific issues or recommendations for female patients with tennis elbow.

Conclusions

As evidence above demonstrates, considerations regarding evaluation and management of shoulder and elbow sports injuries are different in female athletes. Although these patients may present with histories that differ from their male counterparts, as with distal biceps ruptures, the full spectrum of disease pathology should be considered. In addition, the consideration of hormone contribution, differences in the inflammatory cascade, and bone mineral density among female patients might guide different treatment tactics from their male counterparts. Notably, the role of sex in response to treatment remains lacking across the orthopedic literature. Moving forward, it will be critical to study sex as an independent variable in outcome reporting in order to better understand the optimal treatment approaches for each patient. Biologic mediators as well as treatment response are not well understood, and further study is essential to better treating the female athlete population.

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