Shoulder MRI in asymptomatic elite volleyball athletes shows extensive pathology

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ABSTRACT

Objectives Elite overhead athletes, such as volleyball players, are predisposed to shoulder injuries due to repetitive overhead movement and overloading of the shoulder joint and surrounding muscles and ligaments. Returning to play at an elite level following shoulder surgery is often not possible. We hypothesised that MRI of elite volleyball players’ dominant shoulders would demonstrate extensive asymptomatic shoulder pathology that does not prevent the athlete from competing. To test this hypothesis, the objective of this observational study was to evaluate the history, physical examination and MRI findings to determine the incidence of asymptomatic shoulder pathology. We believe this knowledge will improve outcomes in the management of shoulder pain in overhead athletes and prevent unnecessary surgical procedures.

Methods 26 asymptomatic elite volleyball players of the US Men’s and Women’s National Indoor Volleyball Teams underwent MRI (0.27 Tesla) of their dominant shoulders and physical examinations of both shoulders. Asymptomatic was defined as being able to play volleyball without restrictions. The imaging was reviewed by two fellowship-trained musculoskeletal radiologists. Visual Analogue Pain scores, range of motion, strength, University of California, Los Angeles and American Shoulder and Elbow Society outcome scores were measured and recorded.

Results The mean age at the time of MRI was 25.53 years old (range: 21 to 30 years). There were 14 male and 12 female players. 23 athletes had rotator cuff tendinosis (88.5%) and 17 athletes had partial rotator cuff tears (65.4%). 13 of these tears involved the supraspinatus with five moderate-to-high-grade and eight moderate-to-low-grade. Two tears involved the infraspinatus, and there were two subscapularis tears. Six athletes had a labral tear (23.1%) and six additional athletes had labral fraying (23.1%). All MRIs showed abnormal pathology.

Conclusion These findings support the notion that elite-level volleyball players display asymptomatic shoulder joint pathology in their dominant arm, particularly of the rotator cuff and labrum, which do not limit their ability to participate.

Level of evidence V

INTRODUCTION

Elite overhead athletes, such as volleyball players, are predisposed to shoulder injuries. It has been reported that approximately one-quarter of all volleyball injuries involve the shoulder.1 This is likely due to repetitive overhead hitting and overuse of the shoulder joint and its surrounding muscles, tendons, cartilage and ligaments. Shoulder pain ranks highest among volleyball players compared with all other athletes that engage in vigorous upper arm activities.1 This is largely due to the unpredictable nature of the overhead hitting motion in volleyball.1 From a mechanical perspective, the goal of the volleyball hitting motion is to sequentially develop a package of potential energy that is then converted to kinetic energy and transferred to the ball in an efficient and fluid manner.2 In doing so, repetitive tension to the posterior capsule leads to glenohumeral internal rotation deficit (GIRD) and internal impingement of the joint structures. While this adaptation can be viewed as a ‘biomechanical enhancement’ that may improve performance in the sport,3 it can develop further into a potentially painful shoulder or an asymptomatic shoulder that is structurally pathological.

Volleyball players require a delicate balance of shoulder mobility and stability in order to meet the functional demands of overhead hitting. Clinical evaluation of overhead athletes can often be difficult. Sher et al.4 found that 34% of the 96 MRIs they obtained in a normal asymptomatic population contained partial or full-thickness rotator cuff tears, and several studies examining the pitching shoulders of asymptomatic elite baseball pitchers have found 21% to 52% of baseball pitchers to have partial rotator cuff tears and 45% to 62% to have labral tears.6,7 These studies have found no relationship between MRI findings and future shoulder complaints. Thus, abnormal MRI pathology may not always correlate with inability to perform elite overhead sports.

Several studies have documented the less than satisfactory success rates of surgery for overhead
athletes. Andrews reported that 92% of the professional overhead athletes studied were unable to return to a high competitive level without significant shoulder dysfunction after rotator cuff repair surgery. Similarly, only 63% of overhead athletes reviewed in a study conducted by Sayed et al., were able to return to their previous level of play following a superior labrum anterior to posterior (SLAP) lesion repair surgery. In addition, the surgical techniques that have been designed to address these pathologies and restore the shoulder to ‘normal’ can reverse adaptive changes that may have permitted high levels of performance. Therefore, operative management should be the last option after attempting all forms of non-operative management for these athletes.

Determining the significance of MRI findings in the injured shoulder of a throwing athlete is thus difficult because comparative pre-injury MRI scans are not usually available. In this study, we hypothesise that history, physical examination and MRIs of the dominant shoulders of members of the US National Men’s and Women’s Indoor Volleyball Teams would show extensive asymptomatic shoulder pathology which do not prevent the athlete from competing at an elite international level. We believe that this knowledge will potentially improve outcomes in the management of shoulder pain in overhead athletes and prevent unnecessary surgical procedures in this population.

METHODS
Study participants
Inclusion criteria for the study included playing nationally and internationally with no pain or restrictions to activity level at the time of the study (asymptomatic). Exclusion criteria included pain in the dominant shoulder of the athlete, having gone through a rehabilitation programme within the year before data collection, previous surgery on the dominant shoulder and regular use of pain or anti-inflammatory medications at the time of data collection (asymptomatic).

Clinical examination
Each athlete completed a comprehensive survey regarding prior injury and treatment to the dominant shoulder and subsequently underwent a comprehensive physical examination performed by a board-certified orthopaedic surgeon with fellowship training in sports medicine and arthroscopy. During the examination, range of motion was measured using a goniometer; the Jobe’s, Neer’s and Hawkins tests were performed to evaluate for impingement, and the apprehension, relocation and Sulcus tests were used to evaluate for pathological instability. Range of motion was measured in the supine position with the scapula stabilised to assess for posterior capsule contractures and glenohumeral internal rotation deficit. Scapular dyskinesia and periscapular atrophy were evaluated. Strength of the infraspinatus, supraspinatus and subscapularis were determined using manual muscle testing. Patient recorded outcomes including the University of California, Los Angeles shoulder score, and American Shoulder and Elbow Society (ASES) outcome scores were recorded. Descriptive statistics (mean values and ranges) were performed and presented. Two-sided paired t-tests were used to compare variables (ex: dominant vs non-dominant). A p value of less than 0.05 was considered statistically significant.

Imaging
Each athlete underwent a (non-funded) non-arthrogram MRI (Esaote S-Scan 0.27 Tesla) of his or her dominant, asymptomatic shoulder. Only the dominant shoulders of the overhead athletes were imaged due to time constraints, and their dominant shoulder is the primary shoulder involved in the overhead throwing motion. The shoulder MRI protocol list used was as follows: Axial Quick Reference, Coronal proton density (PD), Coronal fast spine echo (FSE) T2, Sagittal FSE T2, Axial PD and Axial Stir. MRI studies were reviewed by two radiologists with fellowship training in musculoskeletal radiology. Both radiologists were blinded. Data was only included when there was interobserver agreement between both radiologists. Data regarding the osseous structures, cartilage, labrum, rotator cuff, muscle atrophy and capsule were recorded.

RESULTS
Demographic data
A total of 26 elite volleyball players from the US Men’s and Women’s National Indoor Volleyball Teams consented to participate in this study based on the inclusion and exclusion criteria outlined above. The mean age of the athletes at the time of evaluation was 25.53 years (range: 21 to 30 years). There were 14 male athletes and 12 female athletes. There were 25 right-handed players and one left-handed player. Ten of the athletes reported a prior injury to their dominant shoulder that was greater than 1 year prior to data collection. All athletes that had previous injuries had completed a full recovery and described themselves as asymptomatic at the time of the study.

Clinical examination data
The mean self-reported ASES score was 90.0 (range: 68.3 to 100), and the mean UCLA score was 32.1 (range: 20 to 35) (Table 1).

<table>
<thead>
<tr>
<th>Score</th>
<th>Result</th>
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<tbody>
<tr>
<td>ASES score</td>
<td>90.0 (range: 68.3–100)</td>
</tr>
<tr>
<td>UCLA shoulder score</td>
<td>32.1 (range 20–35)</td>
</tr>
</tbody>
</table>

On physical examination, the mean flexion, abduction, extension and external rotation at 0 degrees of the subjects’ dominant shoulders (164.4 degrees, 158.5 degrees, 61.6 degrees and 68.0 degrees, respectively) were relatively similar to those of their non-dominant shoulders (164.8 degrees, 162.3 degrees, 62.2 degrees and 66.0 degrees, respectively) (Table 2).

Mean dominant isolated glenohumeral external rotation was 92.1 degrees (range: 66–140 degrees) compared with 82.3 degrees (range: 5–120 degrees) in the non-dominant shoulder. Mean dominant shoulder isolated glenohumeral internal rotation at 90 degrees was 48.5 degrees (range: 22 to 60 degrees) compared with 56.0 degrees (range: 33 to 90 degrees) in the non-dominant shoulder. One athlete (3.8%) had positive apprehension and relocation tests (MRI was positive for labral tear – 10 o’clock SLAP lesion with inferior labral tear), eight (30.7%) had positive Sulcus signs, two had decreased (4/5 on manual muscle testing) rotator cuff strength (one infraspinatus, one subscapularis), four (15.4%) had positive Neer’s sign, four (15.4%) had positive Hawkins’s tests and four (15.4%) had positive Jobe’s tests of their dominant shoulders. Seven (26.9%) athletes had visible muscle atrophy and scapular dyskinesis on physical examination (Table 3).
MRI findings
Twenty-three of 26 athletes had rotator cuff tendinosis (88.5%) on MRI. Among the 23 athletes with tendinosis, 17 had evidence of partial rotator cuff tears (65.4%): 13 supraspinatus (five high-grade and eight low-grade grade) (figure 1), two infraspinatus and two subscapularis (partial superior boarder tears). Six athletes had labral tears (figure 2) (23.1% - four SLAP (15.4%), two anterior-inferior Bankart (7.7%), and six athletes had evidence of labral fraying (23.1%). Thirteen athletes had degeneration of the capsule (50% - 12 anterior and/or inferior (46.2%), one posterior (3.8%), 18 had arthritis of the acromioclavicular joint (69.2%) and 13 had chondromalacia (50%). There were no statistically significant differences detected between different player positions or different genders other than subscapularis pathology which was only detected in male athletes. There were no MRIs with no pathology detected (table 4).

DISCUSSION
Injury to an elite overhead athlete at the professional level can end or severely limit his/her career, with loss of income to the athlete as well as loss of talent to his/her team or organisation. Volleyball players are particularly susceptible to shoulder injuries because of the high-velocity repetitive overhead motion they must perform as well as the unpredictable nature of their overhead swing due to mid-air adjustments to the ball. As opposed to the constrained ball-and-socket hip joint, the glenohumeral joint relies heavily on soft tissue structures for stabilisation rather than bony structures, making it particularly vulnerable to developing mechanical pathology.12

Functional and structural adaptations of the shoulder have been reported in overhead athletes and are thought to develop as a result of the extreme physiological and repetitive demands and loading of the shoulder joint and humerus.11 It has been generally observed that overhead athletes develop adaptive increased external rotation of their dominant humerus and shoulder, which allows for hyper-external rotation of the glenohumeral joint. Such hypermobility can be viewed as advantageous as it allows for greater arm cocking and ball velocity on impact or release. Consequently, this increased velocity leads to excessive strain on the posterior capsule during follow through, leading to scarring, thickening and contracture of the posterior capsule. This internal impingement has been well documented to lead to posterior superior labral tears and articular sided damage to the rotator cuff fibres. Our results support this phenomenon, with a large majority of the MRIs displaying damage to the rotator cuff tendons (88.5%) and almost half (46.2%) showing labral damage. If we had performed MRI arthograms, it is likely that the percentage of athletes having labral damage detected on MRI would have been even higher. We did not want to perform this more invasive test for research purposes because all athletes were asymptomatic and actively playing in national or international volleyball programme; however, repeating the study with MRI arthrogram, or even a high-resolution non-arthrogram MRI (3.0 Tesla) is something to consider in the future. Yet while there may be abnormal pathology present on MRI, the ‘injury’ may not threaten the athlete’s ability to perform in his or her sport at an elite level, as long as capsular flexibility and periscapular strength are maintained.

Wilk and Arrigo,14 termed this seemingly contradictory balance the ‘Throwers Paradox: lax enough to allow excessive external rotation, but stable enough to prevent symptomatic subluxations’. In these overhead activities, the arm is forcefully propelled forward from maximal to near-maximal external rotation to internal rotation and requires the posterior rotator cuff musculature to act eccentrically in order to decelerate or ‘brake’ the arm as it internally rotates and horizontally addsucts across the body.13 In addition, with regard to volleyball, this eccentric force becomes even more prevalent as it must combat the equal and opposite force imparted by the ball on the hand of the athlete.

Table 2  Physical exam results – range of motion (averages)

<table>
<thead>
<tr>
<th>Range of motion</th>
<th>Dominant (degrees)</th>
<th>Non-dominant (degrees)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flexion</td>
<td>164.4 (range: 140–180)</td>
<td>164.8 (range: 142–180)</td>
<td>0.65</td>
</tr>
<tr>
<td>Abduction</td>
<td>158.5 (range: 120–180)</td>
<td>162.3 (range: 131–180)</td>
<td>0.13</td>
</tr>
<tr>
<td>Extension</td>
<td>61.6 (range: 40–80)</td>
<td>62.2 (range: 40–80)</td>
<td>0.45</td>
</tr>
<tr>
<td>External rotation (at 0 degrees abduction)</td>
<td>68.0 (range: 42–90)</td>
<td>66.0 (range: 40–90)</td>
<td>0.25</td>
</tr>
<tr>
<td>External rotation (at 90 degrees abduction)</td>
<td>92.1 (range: 66–140)</td>
<td>82.3 (range: 5–120)</td>
<td>0.01</td>
</tr>
<tr>
<td>Internal rotation (at 90 degrees abduction)</td>
<td>48.5 (range: 22–60)</td>
<td>56.0 (range: 33–90)</td>
<td>0.03</td>
</tr>
</tbody>
</table>

Table 3  Physical exam results – stability, laxity, rotator cuff and strength testing

<table>
<thead>
<tr>
<th>Test</th>
<th>Positive results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jobe’s test</td>
<td>4/26 (15.4%)</td>
</tr>
<tr>
<td>Neer’s sign</td>
<td>4/26 (15.4%)</td>
</tr>
<tr>
<td>Hawkins test</td>
<td>4/26 (15.4%)</td>
</tr>
<tr>
<td>Apprehension/relocation test</td>
<td>1/26 (3.8%) *MRI positive for labral tear</td>
</tr>
<tr>
<td>Sulcus sign</td>
<td>8/26 (30.8%) *6/26 bilateral</td>
</tr>
<tr>
<td>Decreased rotator cuff strength (4/5)</td>
<td>2/26 (7.7%)</td>
</tr>
<tr>
<td>Muscle atrophy</td>
<td>7/26 (26.9%)</td>
</tr>
</tbody>
</table>

Figure 1  Representative image of rotator cuff tearing seen in the study sample compared with a normal control.
The sport of volleyball requires various types of movement patterns involving repetitive, ballistic impact loads, which could lead to a variety of pathologies. Volleyball athletes are most vulnerable to stress on the shoulder during overhead serving and ‘spiking.’ Rokito et al.,15 conducted a study in which shoulder vulnerability to stress on the shoulder during overhead serving and ‘spiking’ led to a variety of pathologies. Volleyball athletes are most vulnerable to stress on the shoulder during overhead serving and ‘spiking.’ Rokito et al.,15 conducted a study in which shoulder vulnerability to stress on the shoulder during overhead serving and ‘spiking,’ led to a variety of pathologies. Volleyball athletes are most vulnerable to stress on the shoulder during overhead serving and ‘spiking.’ Rokito et al.,15 conducted a study in which shoulder vulnerability to stress on the shoulder during overhead serving and ‘spiking,’ led to a variety of pathologies.

**Table 4** MRI results

<table>
<thead>
<tr>
<th>Pathology</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rotator cuff tendinosis</td>
<td>23/26 (88.5%)</td>
</tr>
<tr>
<td>Rotator cuff tearing</td>
<td>17/26 (65.4%)</td>
</tr>
<tr>
<td>Supraspinatus (figure 1)</td>
<td>13/26 (50.0%)</td>
</tr>
<tr>
<td>Infra spinatus</td>
<td>2/26 (7.7%)</td>
</tr>
<tr>
<td>Subscapularis</td>
<td>2/26 (7.7%)</td>
</tr>
<tr>
<td>Labral tearing and/or fraying (figure 2)</td>
<td>12/26 (46.2%)</td>
</tr>
<tr>
<td>Acromioclavicular joint degeneration</td>
<td>18/26 (69.2%)</td>
</tr>
<tr>
<td>Glenohumeral joint degeneration</td>
<td>13/26 (50.0%)</td>
</tr>
<tr>
<td>Capsule degeneration</td>
<td>13/26 (50.0%)</td>
</tr>
</tbody>
</table>

As a result, some level of GIRD was present in the majority of athletes studied, however, only four had pathological GIRD defined by an internal rotation deficit greater than 25 degrees. The mean internal rotation at 90 degrees was almost 10 degrees lower in the dominant shoulders of these athletes compared with their non-dominant shoulders, and the difference was statistically significant. Challoumas et al.,17 reviewed the literature on GIRD in volleyball players and confirmed the existence of GIRD in the dominant shoulder with the additional observation that unlike other overhead sports, the GIRD in volleyball players appeared to be anatomical as a response to repetitive movements overhead and not associated with shoulder pain/injury. Internal rotation deficit has also been correlated with difference in scapular positioning, which can negatively affect the normal function of the shoulder.21 Researchers have speculated as to whether these structural adaptations compromise shoulder stability, thus exposing the overhead athlete to shoulder injury. The stability tests (aprehension and relocation tests) performed on all athletes in this study were negative bilaterally with the exception of one. Certainly, the high prevalence of GIRD and the presence of four athletes with severe GIRD, despite a regular posterior capsule stretching and periscapular strengthening programme among athletes in US volleyball, was concerning to the authors. This stresses the importance of regularly examining overhead athletes and identifying those with GIRD so they can be enrolled into a more formal and aggressive rehabilitation programme prior to the development of symptoms. This is especially important given the limitations of MRI in diagnosing GIRD.

Connor et al.,5 conducted an investigation into the MRI findings of asymptomatic collegiate baseball pitchers and tennis players. They found that 40% of athletes, comparable to our finding of 65.4%, had a partial or full thickness tear of the rotator cuff on the dominant shoulder. They conducted 5-year follow-up examinations with these athletes, at which time all presented asymptomatic with regard to their shoulders. Several other studies examined the MRIs of baseball pitchers with similar findings.16-7 Lesniak et al.,9 specifically investigated the correlation between the presence of abnormal MRI findings in the dominant shoulders of Major League Base ball pitchers and future time spent by the athletes on the disabled list. They found that the imaging findings did not have any such predictive value. Interestingly, in an examination of shoulder MRIs of members of the Swiss National European Handball Team during their career and during retirement, Schär et al.,19 discovered not only that MRI changes correlated poorly with clinical symptoms, but that pathology findings in the throwing shoulder did not progress after retirement, and even sometimes were seen to have resolved.

Our results lead us to conclude that what has been studied in baseball pitchers and handball players also applies to volleyball players. It is therefore reasonable to conclude that MRI findings such as rotator cuff and labral tears do not necessarily indicate an immediate future risk to athletes and the need for surgery; rather, these athletes should first undergo a formal rehabilitation programme for posterior capsule mobilisation as well as periscapular strengthening.

There are several limitations to this study. First, our sample size was only 26 athletes. We wanted to enrol only US volleyball players who were actively playing with absolutely no pain or limitation, and as a result, due to the already small pool of elite volleyball players, our sample size was small. Time constraints with regard to coordinating with the schedules of the professional athletes as they competed internationally also played a role in the limited sample size. There were also several technological limitations. An MRI of the throwing shoulder is challenging to perform, as some athletes have poor pain tolerance and are difficult to keep still for the duration of the scan. The limitations of MRI in diagnosing GIRD were also demonstrated. The high prevalence of asymptomatic and limited MRI results correlated poorly with clinical symptoms, and pathology findings did not progress after retirement.
role in the small sample size. In addition, we used a low-field MRI machine (T 0.27) to perform the imaging studies without intra-articular contrast. A prior study comparing non-contrast low-field shoulder MRI to arthroscopic findings showed high diagnostic accuracy of rotator cuff pathology, however labral pathology was more difficult to identify. An MRI arthrogram may have allowed for improved diagnostic accuracy in evaluating labral pathology in-particular, but we did not want to perform an invasive study on an asymptomatic athlete during their playing season. Finally, there were no previous MRIs, physical examinations or outcomes scores to compare our data to. Long-term follow-up of these volleyball players would strengthen the study to provide more insight into the future risk for injury, and a future study is being designed to do this.

Given these results, it is important to use a conglomerate of evidence modalities to guide management of overhead athletes. The decision for surgery should not be made solely based on imaging findings. Strong consideration should be given to non-operative management options such as exercise interventions and/or data-based interval hitting programme. Wright et al. reviewed the literature examining ‘exercise prescriptions’ for overhead athletes with shoulder pathology, demonstrating great variability though strong evidence to support the use of single-plane, open chain upper extremity exercises performed below 90 degrees of elevation and closed upper extremity exercises.

CONCLUSION

The dominant shoulder of an elite overhead athlete, such as a volleyball player, is placed under significant repetitive stress and is at risk for damage to the structures of the joint. However, this damage can remain asymptomatic even under the repetitive stress incurred throughout an athlete’s career. Our current study is the first that we know to evaluate the dominant shoulders of asymptomatic, elite volleyball players. We found that MRI findings in elite overhead athletes are highly likely to include abnormalities that could be considered surgical; however, these findings are often asymptomatic. It is important to recognise that there is a high rate of asymptomatic, yet abnormal MRI findings in this patient population. Therefore, we recommend that operative management on overhead athletes only be utilised following significant non-operative treatment as patient symptoms may not correlate with MRI findings.

Contributors Each author listed above has contributed to the planning, conduct and reporting of the work described in the article as follows. CSL: corresponding author and critical contributor to the project conception and design, study planning, as well as primary physical examiner and manuscript reviewer. NHG: critical contributor to the recruitment of study participants, acquisition of data, data analysis/interpretation/reporting, as well as manuscript production and review. SMD: critical contributor to study planning, IRB approval, recruitment, data acquisition and manuscript review. MLD: critical contributor to data acquisition and manuscript review. AB: critical contributor to project design, recruitment and manuscript review. JW: critical contributor to project design, recruitment and manuscript review. EHL: critical contributor to radiologic data acquisition, manuscript review. RKL: critical contributor to radiologic data acquisition, manuscript review. WBS: critical contributor to the project conception and design, study planning and manuscript review.

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Data availability statement Data are available upon reasonable request.

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REFERENCES