

# Shoulder complaints more likely in volleyball players with a thickened bursa or supraspinatus tendon neovessels

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Shoulder problems are common in volleyball and greatly impede both training and player performance. Subacromial bursa (SAB) thickening and tendon neovascularity have shown relevance in other populations, but their relationship with the development of shoulder complaints has not been investigated in volleyball players or overhead-throwing athletes. The study aim was to examine the role of SAB thickness, neovascularization of the supraspinatus tendon, shoulder strength, range of motion (ROM), player position, and age in the development of shoulder complaints in professional volleyball players. Players underwent preseason baseline testing ( $n = 86$ ) and reported shoulder complaints during the subsequent 12-week period. Generalized estimating equations were used to model for probabilities of complaints after adjusting for player position, SAB side-to-side difference, neovessel presence, shoulder external rotation (ER) ROM, and age. Outside hitters and opposites were 12.2-fold more likely to develop complaints, and greater shoulder ER ROM increased risk by 8% for each additional degree. A side-to-side difference in SAB thickness  $\geq 0.3$  mm in the dominant compared with the non-dominant arm was associated with a 10.2-fold increased risk. Those with neovessels were 6.5 times more likely to develop complaints. Players without neovessels and with normal SAB thickness were very unlikely to develop complaints. This stark contrast to players with neovessels or increased SAB thickness, where nearly half of the players developed complaints, is of interest. Players with current complaints at baseline presented with greater IR:ER strength ratios; however, neither strength nor IR ROM at baseline was associated with an increased risk of developing complaints.

## KEYWORDS

overhead athlete, rotator cuff, shoulder pain, shoulder ultrasound, volleyball injuries

## 1 | INTRODUCTION

Elite volleyball is a fast-paced, hard-hitting sport that sees large loads transmitted through the athlete's shoulder. While shoulder motion is similar between the volleyball spike and the throwing motion in other overhead sports, the spike and jump serve have unique biomechanical properties that differ from sports such as baseball and tennis.<sup>1-3</sup> The stresses

applied to the arm during overhead attacks result in a high prevalence of shoulder problems.<sup>4-6</sup> As many as 23%-43% of competitive volleyball players report shoulder complaints during a given season.<sup>4,7,8</sup> Furthermore, 58% of collegiate club-level players report a history of shoulder problems.<sup>4</sup> Still, most players continue to train and compete, with little to no time away from the sport. The majority of amateur players with spiking-related shoulder pain report having pain hitting

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to all areas of the court (60%) and pain limiting how hard they can spike (77%).<sup>9</sup>

Little is known regarding the risk factors that contribute to shoulder-related complaints in elite volleyball players and prospective studies are limited.<sup>7,10</sup> Limited evidence suggests that muscle imbalance and playing position may represent risk factors for shoulder problems, while range of motion (ROM), humeral torsion, and age have been associated with injuries in other overhead sports.<sup>4,7,10-14</sup> In addition to these traditional risk factors, examination of the shoulder's subacromial bursa (SAB) and neovascularity of the supraspinatus tendon may be of interest. Thickening of the SAB has been associated with shoulder pain and injuries in overhead athletes. In open water endurance swimmers, SAB thickness was related to both training volume and pain after completion of the event.<sup>15</sup> SAB thickness has not been investigated in volleyball players or other overhead athletes, and its relationship with the development of shoulder complaints is unknown.

A recent systematic review and meta-analysis documented that tendon abnormalities on ultrasound were associated with a five-fold risk of future symptoms in lower extremity tendinopathies.<sup>16</sup> Additionally, a large prospective study in runners found a 6.9-fold increased risk of Achilles tendinopathy in those with neovascularization.<sup>17</sup> It is unknown whether similar findings can be expected in the upper extremity. The presence of neovessels in overhead athletes and their relationship with symptoms should be explored.

Prospective studies examining traditional risk factors for shoulder complaints in elite volleyball are needed, and the inclusion of shoulder tendon and bursa characteristics is of interest. Therefore, the aim of this prospective cohort study was to examine the role of SAB thickness, neovascularization of the supraspinatus tendon, shoulder strength, ROM, player position, and age in the development of shoulder-related complaints in professional volleyball players.

## 2 | METHODS

### 2.1 | Study design

Professional volleyball players were followed for 12 weeks after preseason baseline testing. Players from three professional men's club teams in Qatar participated during the 2016-2017 club season and national team players competing during at least one of three consecutive national team seasons (2015-2017) were included. A group of testers visited each team prior to a preseason training session to minimize the acute effects of exercise on the neovascular assessment. All players, regardless of current or past shoulder problems, were eligible for study inclusion and invited to participate. Players needed to remain with the team during the

subsequent 12 weeks to be included. A total of 86 preseason musculoskeletal assessments were performed between May 2015 and May 2017. Participants provided informed consent, the rights of participants were protected, and study approval was obtained from the Anti-Doping Lab Qatar Institutional Review Board.

### 2.2 | Baseline testing

Trained physical therapists and strength and conditioning coaches with experience in volleyball and the musculoskeletal screening of athletes conducted the tests. A sports physical therapist with >10 years of musculoskeletal ultrasound experience performed all humeral torsion, SAB thickness, and neovascularization assessments, blinded to the results of the baseline questionnaire. In addition, player height, weight, date of birth, position, and dominant arm were recorded.

### 2.3 | Shoulder strength

We measured shoulder external rotation (ER) and internal rotation (IR) strength using a handheld dynamometer (HHD; ergoFET500, Hoggan Scientific LLC, Salt Lake City, UT, USA). The maximum score from 3 trials was recorded using an eccentric "break test."<sup>18</sup> Scores were converted to percent body weight and calculations made to determine each player's IR:ER strength ratio. Strength tests were performed with the athlete standing, feet shoulder width apart, arm at the side, and elbow bent 90°. The HHD was positioned in-line with the ulnar styloid process. The athlete rotated the arm into the HHD for 3 seconds, performing a maximal isometric contraction, before the examiner applied a small overpressure to complete the "break test." When the examiner felt the arm start to give way, he stopped the test and recorded the value. Care was taken to avoid compensatory movements by the athletes and limit the motion to shoulder rotation only.

### 2.4 | Range of motion

Glenohumeral ER and IR passive ROM were measured in supine for both the dominant and non-dominant arms, similar to methods previously described.<sup>12,19</sup> The arm was abducted 90° in the frontal plane and elbow bent 90°. The examiner stabilized the scapula and gradually rotated the arm into maximal ER and stopped at end range or when the athlete reported he could not rotate any further. An inclinometer placed flat along the distal portion of the ulna was used to determine the angle. This process was repeated for IR and end range was determined when a firm end feel was felt without compensatory movements or when the athlete reported

he could not rotate any further. When necessary, the athlete's arm was placed on a towel or the examiner's thigh to maintain alignment of the upper arm in the frontal plane. Total rotational ROM was calculated from combining ER and IR values. Glenohumeral IR was also measured in 90° of shoulder flexion. The examiner rotated the arm into maximal IR and stopped when a firm end feel was felt prior to shoulder elevation or compensation.

## 2.5 | Humeral torsion

Humeral torsion was measured for both arms using a diagnostic ultrasound device (MyLab25 Gold with LA523 transducer, Esaote, Genoa, Italy) and a method previously described with excellent inter-tester reliability and a minimal detectable change (MDC) of  $2.9^\circ \pm 2.6^\circ$ .<sup>20</sup> The amount of humeral torsion in the dominant arm compared with the non-dominant arm was calculated. An adjusted measure of dominant arm ER and IR ROM that accounts for this side-to-side difference in humeral torsion was created so that glenohumeral ROM could be adequately compared with the non-dominant arm. This calculation kept the non-dominant arm ROM values the same while subtracting the humeral torsion side-to-side difference from the dominant arm ER ROM and adding the difference to the IR ROM.

## 2.6 | Subacromial bursa thickness and neovascularity

With the athlete seated, and the arm supported at approximately 30° of scapular plane abduction (Figure 1), the bicipital groove was identified in a transverse view, and then immediately lateral to this, now in a longitudinal plane, the supraspinatus insertion was carefully visualized from anterior to posterior. After examining the visible tendon from anterior to posterior, color Doppler was activated, and the presence or absence of vessels within the supraspinatus

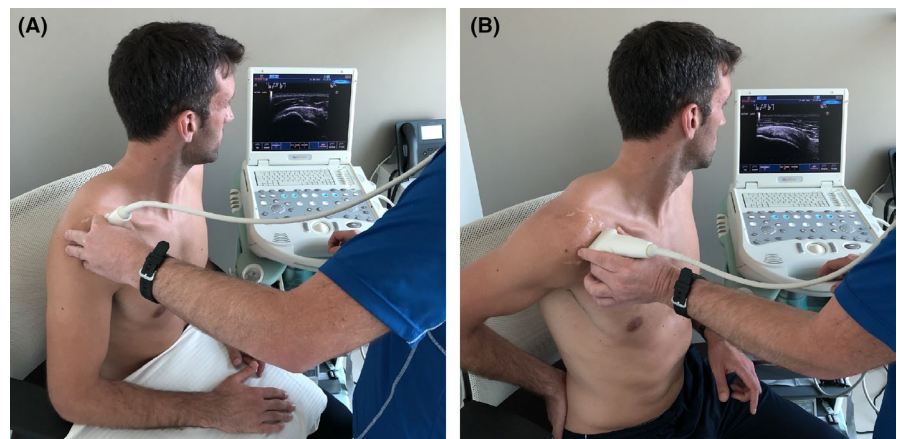
tendon was noted using a similar approach. Neovascularity was recorded as none, slight (appearance of one vessel, not more than approximately 1 mm in diameter), or marked (more than one vessel, or one vessel more than approximately 1 mm in diameter). Ultimately, our final analysis included a binary classification of vascularity present or not present, similar to previous research.<sup>21</sup> Finally, with the Doppler disengaged, the SAB was examined for the point where it was seen to be thickest, as the location of maximum thickness is often utilized.<sup>22-24</sup> This distance was documented, measuring the depth of fluid in the bursa, without including the peribursal fat tissue.

## 2.7 | Monitoring of shoulder problems

Shoulder problems were reported by players at baseline and throughout the 12-week follow-up period by completing the Oslo Sports Trauma Research Center (OSTRC) Overuse Injury Questionnaire.<sup>25</sup> Players reported any pain related to their sport and the extent to which shoulder problems affected participation, training volume, and performance. Shoulder problems were defined as “pain, aching, stiffness, looseness, or other complaints.”<sup>25</sup> The team physical therapist or strength and conditioning coach was responsible for providing and collecting paper copies of the questionnaire. Team representatives were encouraged to have players complete the questionnaires every 2 weeks at a minimum, with the goal of completing six questionnaires during the 12-week period. A player needed to complete at least three questionnaires to be included in the analysis.

## 2.8 | Statistical methods

Players representing the national team for multiple seasons were included each year. This resulted in 56 unique players completing 86 player-seasons. As the number of players completing baseline tests varied from year to year,



**FIGURE 1** Modified subject positioning (A) during neovascular assessment of the Supraspinatus tendon on ultrasound — used to avoid possible “wringing out” of the tendon that may limit vascular assessment when the tendon is stretched in the traditional position (B) [Colour figure can be viewed at [wileyonlinelibrary.com](http://wileyonlinelibrary.com)]

results were analyzed using these 86 player-seasons. On five occasions, the player tested was not included in the final analysis. This was secondary to missing a baseline questionnaire ( $n=4$ ) or incomplete follow-up questionnaires as a result of changing clubs ( $n=1$ ). Baseline test results were reported for all of the remaining 81 player-seasons, but only those without baseline shoulder complaints were included in the prospective risk factor analysis. Preliminary inferential statistical analyses were performed to determine which baseline variables were significantly different ( $P \leq .05$ ) between: (1) players without shoulder complaints; and (2) players who developed shoulder complaints during the 12-week follow-up. These variables were then assessed and considered for inclusion into the final model. SAB side-to-side difference was further evaluated by examining the area under the curve of a receiver operating characteristic (ROC) curve to determine an appropriate cutoff value for players with and without substantially thicker bursas between the dominant and non-dominant arms. Generalized estimating equations (GEEs) were used to model for probabilities of shoulder complaints after adjusting for all factors (position, SAB side-to-side difference, neovessel presence, shoulder ER ROM, age) and repeated variables (team, subject) using unstructured working correlations. Analyses were conducted using SPSS version 21 (IBM Corporation, New York, NY, USA).

### 3 | RESULTS

A total of 81 player-seasons were analyzed, including baseline testing and 12-week questionnaire follow-up. In 22 (27.2%) cases, the player reported shoulder complaints at baseline while the remaining 59 (72.8%) reported no baseline complaints. Of these remaining 59 player-seasons, 16 (27.1%) developed complaints during the subsequent 12 weeks. Players completed 5.7 questionnaires on average (SD 1.5) and no differences were observed between players who developed complaints and those who did not. The majority of players with complaints reported shoulder problems that affected their performance (84.2%) and a need to reduce training volume secondary to shoulder complaints (73.7%).

Table 1 shows the relationship between preseason musculoskeletal screening measures and development of shoulder complaints for the 59 player-seasons without baseline complaints.

#### 3.1 | Player position and age

Outside hitters (11 of 19) and opposites (2 of 4) were most likely to develop shoulder problems; few middle blockers

(2 of 19), setters (0 of 12), and liberos (1 of 5) developed complaints. When combining position groups, outside hitters and opposites were 12.2-fold more likely to develop complaints compared with other players (Table 2). Age was also a significant protective factor. For a 1-year increase, a player was 21% less likely to develop complaints (Table 2).

#### 3.2 | Shoulder strength and range of motion

Collectively, players presented with significantly greater shoulder ER ROM (dominant: 129°, 95% CI 125-133; non-dominant: 122°, 95% CI 119-125) and less shoulder IR ROM (dominant: 82°, 95% CI 78-86; non-dominant: 88°, 95% CI 84-91) in their dominant versus non-dominant arms. However, no statistically significant side-to-side differences were observed when humeral torsion was accounted for (dominant ER: 118°, 95% CI 114-122; dominant IR: 93°, 95% CI 89-98). We could not detect any differences in dominant shoulder IR ROM between players with baseline complaints and those without complaints (measured IR ROM: 76° vs 84°,  $P = .057$ ; adjusted IR ROM: 89° vs 95°,  $P = .195$ ; Table 1).

Having greater shoulder ER ROM increased a player's risk of developing complaints by 8% for every additional degree (Table 2). Therefore, an increase of 12° of ER ROM — the group mean difference between those who developed complaints and those who did not — increased a player's risk by 96%.

Greater IR strength and greater IR:ER strength ratios were observed in players with baseline complaints (Table 1); however, no strength differences were observed between players who went on to develop complaints and those who did not.

#### 3.3 | SAB thickness and neovessel presence

The majority of players (81%) had increased SAB thickness in the dominant shoulder compared with the non-dominant side. Players without neovessels present and without a substantial increase in SAB thickness in their dominant arm rarely developed complaints (Figure 2). ROC analysis revealed an optimal SAB thickness side-to-side difference cutoff point of 0.3 mm. Having a  $\geq 0.3$  mm increased SAB thickness in the dominant arm compared with the non-dominant arm was associated with a 10.2-fold increased risk of developing complaints (Table 2). Those with neovessels present were 6.5 times more likely to develop shoulder complaints (Table 2).

**TABLE 1** Relationship between preseason musculoskeletal screening measures and development of shoulder complaints in professional volleyball players without complaints at baseline (n = 59)

Category	Players with baseline complaints (n = 22)		Players without baseline complaints			
			Developed season complaints (n = 16)		No complaints (n = 43)	
	Mean (95% CI)	SD	Mean (95% CI)	SD	Mean (95% CI)	SD
Player characteristics						
Age (y)	25.1 (23.7-26.5)	3.1	23.5 (21.4-25.6)**	3.9	26.5 (25.2-27.9)	4.3
Body weight (kg)	90.9 (87.1-94.7)	8.6	89.5 (86.7-92.2)	5.1	90.3 (87.8-92.8)	8.2
SAB thickness (mm)						
Dominant arm	0.89 (0.73-1.06)	0.37	0.87 (0.63-1.11)	0.44	0.75 (0.66-0.85) <sup>a</sup>	0.30
Non-dominant arm	0.56 (0.43-0.70)	0.30	0.44 (0.34-0.54)**	0.19	0.58 (0.49-0.67) <sup>a</sup>	0.30
Side-to-side difference (d-nd)	0.33 (0.12-0.54)	0.48	0.44 (0.22-0.65)**	0.41	0.17 (0.08-0.26) <sup>a</sup>	0.29
Range of motion — dominant shoulder (degrees)						
External rotation (measured)	128 (120-137)	19	136 (126-146)	18	126 (122-131)	15
Internal rotation (measured)	76 (68-83)	17	85 (77-94)	16	84 (78-90)	19
External rotation (adj.) <sup>b</sup>	115 (107-124)	19	127 (118-137)**	18	115 (110-121)	17
Internal rotation (adj.) <sup>b</sup>	89 (81-97)	18	94 (85-104)	18	95 (88-102)	22
Total range of motion	204 (191-218)	30	221 (213-229)**	15	210 (203-218)	24
Humeral torsion difference	13 (11-16)	6	9 (4-15)	10	11 (9-14)	8
Range of motion — non-dominant shoulder (degrees)						
External rotation (measured)	123 (116-130)	16	123 (115-130)	14	120 (117-124)	11
Internal rotation (measured)	83 (75-91)	18	93 (87-99)	11	88 (82-93)	17
Total range of motion	206 (194-219)	29	216 (208-224)	15	208 (202-214)	19
Strength — dominant shoulder (% body weight)						
External rotation	0.21 (0.19-0.24)	0.05	0.24 (0.22-0.26)	0.04	0.23 (0.21-0.24)	0.05
Internal rotation	0.32 (0.30-0.35)*	0.06	0.29 (0.28-0.31)	0.03	0.29 (0.28-0.31)	0.05
IR:ER ratio	1.63 (1.34-1.91)*	0.64	1.26 (1.15-1.37)	0.21	1.35 (1.26-1.44)	0.30

Abbreviations: d, dominant; ER, external rotation; IR, internal rotation; nd, non-dominant; SAB, subacromial bursa.

<sup>a</sup>One player did not have SAB thickness measurements performed (n = 42).

<sup>b</sup>An adjusted measure of external and internal rotation range of motion that accounts for the amount of humeral torsion in the dominant arm compared with the non-dominant arm.

\*Players with baseline complaints significantly different from players without baseline complaints ( $P \leq .05$ ).

\*\*Players who developed season complaints significantly different from group with no complaints ( $P \leq .05$ ).

The GEE analysis revealed that position, SAB side-to-side difference, neovessel presence, shoulder ER ROM, and age all had substantial influence in the final model (Table 2).

## 4 | DISCUSSION

This is the largest prospective study to date exploring risk factors for shoulder complaints in volleyball players and the first prospective study to examine the relationship between SAB thickness and neovascularization in the development of shoulder complaints in overhead athletes. Athletes with a substantially thicker SAB in their dominant shoulder and

those with neovessels present were both much more likely to develop complaints. Younger players and players with greater shoulder ER ROM were also at increased risk. Finally, outside hitters and opposites were 12.2-fold more likely to develop shoulder complaints compared with their teammates.

### 4.1 | Increased SAB thickness associated with shoulder complaints

Overhead athletes presenting with shoulder pain and a thickened SAB is nothing new. In this study, SAB thickening in the dominant arm was a normal finding among professional

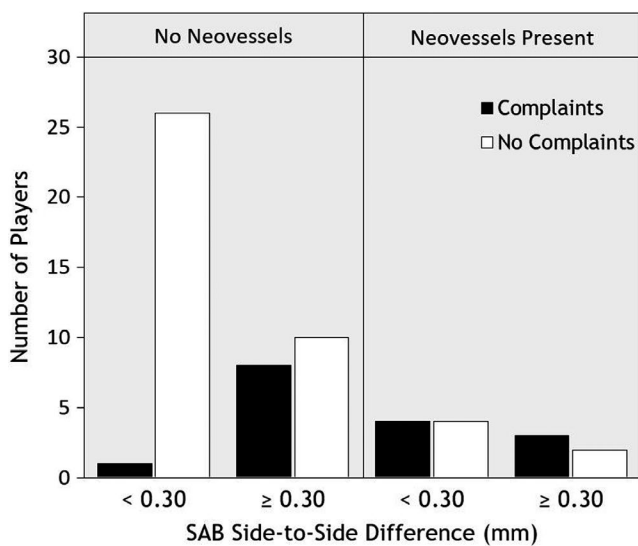
**TABLE 2** Generalized estimating equations displaying the likelihood of in-season shoulder complaints based on position, side-to-side difference in subacromial bursa thickness, neovessel presence, shoulder ER ROM, and age (n = 58, players without baseline shoulder complaints)

	B	SE	Wald	df	P value	Odds ratio (95% CI)
Position (Out/Opp vs MB/S/L) <sup>a</sup>	2.50	1.03	5.85	1	.016	12.15 (1.60-92.07)
SAB difference ( $\geq 0.3$ mm, yes/no)	2.33	0.86	7.34	1	.007	10.24 (1.90-55.16)
Neovessel presence (yes/no)	1.88	0.99	3.58	1	.058	6.52 (0.94-45.50)
Shoulder ER ROM ( $^{\circ}$ )	0.07	0.04	3.17	1	.075	1.08 <sup>b</sup> (0.99-1.17)
Age (y)	-0.23	0.10	5.88	1	.015	0.79 (0.66-0.96)

Abbreviations: B, beta; *df*, degrees of freedom; ER, external rotation; ROM, range of motion; SAB, subacromial bursa; SE, standard error; Wald, Wald chi-square.

<sup>a</sup>Position grouped as outsides/opposites vs middle blockers/setters/liberos.

<sup>b</sup>For every 1 $^{\circ}$  of change.



**FIGURE 2** Development of shoulder complaints in professional volleyball players based on preseason ultrasound findings: players without substantial increased side-to-side subacromial bursa (SAB) thickness (<0.3 mm) and without neovessels present in the dominant arm rarely developed complaints (n = 58, players without baseline shoulder complaints)

volleyball players. However, a substantial side-to-side difference was associated with shoulder complaints. These findings are consistent with previous work in endurance swimmers that found swimmers with pain 1 week post-race had greater SAB thickness than those without pain.<sup>15</sup> This relationship between SAB thickness and pain is also supported in cross-sectional studies. A small study of waterpolo players reported observation of subacromial bursitis on US in 63% of players with pain.<sup>26</sup> In a larger group of non-athletes with unilateral shoulder pain during overhead activity, increased SAB thickness was observed in the symptomatic shoulder compared with the non-symptomatic side.<sup>24</sup>

The relationship between SAB thickness and shoulder pain appears clear, but may be more nuanced as it also

appears to be a normal adaptation in response to loading of the shoulder. Among endurance swimmers, SAB thickness increased over a 4-month training period and correlated with swimming volume.<sup>15</sup> Our study found that the majority of players had greater SAB thickness in the dominant shoulder compared with the non-dominant arm. This likely represents an adaptation in the dominant arm, due to the repetitive unilateral nature of spiking throughout a player's career. It has been suggested that asymptomatic thickening of the SAB may be common, similar to observations of asymptomatic rotator cuff tears.<sup>27</sup>

It is difficult to compare specific values across studies as populations and methods differ. One study in young healthy subjects reported a MDC of 0.18 mm when measuring SAB thickness.<sup>23</sup> Another study reported an intra-rater MDC of 22% and inter-rater MDC of 26%; equivalent to 0.18 and 0.21 mm based on the mean dominant arm SAB thickness in our study (0.82 mm).<sup>28</sup> With this in mind, the side-to-side cutoff of 0.3 mm determined from the ROC analysis appears reasonable to separate those with substantially thickened bursas.

## 4.2 | Neovascularization of the supraspinatus tendon may not be so different to that of the lower extremity tendons

Research examining patellar and Achilles tendons has found neovascularization and tendon abnormalities to represent risk factors for future development of symptoms.<sup>16,17</sup> However, there is limited understanding of the relationship between neovascularization and shoulder complaints in general, let alone in overhead athletes. One cross-sectional study in overhead athletes with subacromial pain syndrome suggests there may be a relationship, as there was supraspinatus tendon vascularization in 85% of painful shoulders compared

with 38% of non-painful shoulders.<sup>29</sup> Building on this, our prospective findings revealed that players with neovessels were 6.5-fold more likely to develop future complaints.

Neovascular assessment of the shoulder can be performed with near-perfect reliability, but methodological differences make comparisons difficult between studies.<sup>30</sup> Two previous studies in non-athletic populations with rotator cuff tendinopathy investigated neovessels in both the tendon and the bursa.<sup>21,31</sup> Inclusion of peribursal neovascularization increased the prevalence from 45% to 65% in symptomatic shoulders and 15% to 25% on the asymptomatic side.<sup>31</sup> We observed similar findings in the 22 players with shoulder complaints at baseline; 12 (55%) had neovessels in their dominant shoulder and only 1 (5%) on the non-dominant side. In the entire sample, 22% had neovessels in the dominant arm and 9% in the non-dominant arm.

Combining the neovessel and SAB thickness results (Figure 2) provides additional insight. Players without neovessels and without increased SAB thickness were unlikely to develop shoulder complaints (4%). This is in stark contrast to players with neovessels and/or increased SAB thickness; as many as 48% developed complaints. The reasoning for this is unknown, but it is of clinical interest to determine how to properly load the shoulder of players with increased SAB thickness or neovascularization in a manner that minimizes future complaints.

### 4.3 | Our novel method to assess neovascularization may avoid “wringing out” the supraspinatus tendon

When assessing neovascularity in the lower extremity, joints are traditionally examined in a relaxed position, avoiding significant tension to the tendon.<sup>32,33</sup> Conventional grayscale ultrasound assessment of the supraspinatus tendon places the tendon in a stretched position, allowing good visualization of the tendon. However, this position is believed to “wring out” the tendon, leading to decreased blood flow.<sup>34</sup> Two previous studies examining neovessels in the shoulder noted that positioning of the arm and the stretch placed on the tendon may alter findings.<sup>30,31</sup> While neovascularization of the supraspinatus tendon has previously been observed with the tendon under stretch, the current study found substantial prospective value through a slight modification of the shoulder position.

### 4.4 | Outside hitters and opposites at greatest risk for developing shoulder complaints

Outside hitters and opposites developed substantially more shoulder complaints than other position groups. This is consistent with previous findings in collegiate volleyball players — attackers (outside hitters, opposites, and middles) reported a greater prevalence of shoulder pain than setters and liberos.<sup>4</sup> A

greater proportion of outside hitters than other players also experienced shoulder injuries during major FIVB tournaments.<sup>35</sup> In the current study, very few middles reported shoulder complaints. It is unclear from the literature whether middles typically have fewer shoulder complaints than other attackers or whether this is related to our limited sample size. Setters and middles perform the greatest volume and frequency of jumps during training and competition,<sup>36</sup> but have fewer shoulder complaints. This discrepancy in complaints compared with outside hitters and opposites is likely related to decreased attack load and different hitting mechanics.

### 4.5 | Range of motion, strength, and age as risk factors

A recent systematic review found volleyball players, on average, have more shoulder ER and less IR ROM in the dominant arm compared with the non-dominant arm.<sup>13</sup> This greater shoulder ER motion appears to be a natural adaptation to the sport, resulting from increased humeral torsion in the dominant arm. This was evident in the current study as substantial side-to-side differences were observed in the raw ER and IR measurements, but those differences dissipated after accounting for humeral torsion. Additionally, the observation of apparent ER gain and concomitant glenohumeral IR deficit existed within our population and became problematic when ER gain led to greater total rotational ROM. Players with the greatest ER motion were at increased risk of developing shoulder complaints, but no relationship between IR ROM and shoulder complaints was observed. It is unclear from this and previous studies as to the cause of symptoms associated with ER gain.<sup>37</sup>

Previous cross-sectional studies have reported mixed findings on a possible relationship between shoulder strength imbalance and previous shoulder injury.<sup>4,7,13,38</sup> One prospective study with 16 players suggests an association between muscle strength imbalance and the risk of shoulder problems.<sup>10</sup> In the current study, we found no relationship between the risk of shoulder complaints and shoulder rotation strength or IR:ER strength ratio.

For clinicians, it is of interest that players with current shoulder complaints at baseline presented with greater IR:ER strength ratios and (non-significantly) less IR ROM. These differences could be acute or long term in nature, and while we did not detect any relationship with subsequent complaints, it is unknown whether serial testing on a daily or weekly basis would allow for early detection of deficits prior to the onset of substantial complaints. Additionally, younger players were found to be at increased risk for developing shoulder complaints. This was surprising; it may be that the older players represented a select group of “survivors” or that

the younger players were not yet adapted to this elite level of training and match play.

## 4.6 | Methodological considerations

Our findings may have implications for other overhead athletes, but as we only included professional volleyball players, extrapolation of these results to other sports and different levels should be done with caution. Direct comparison of the SAB thickness and neovessel assessments to previous studies is difficult as different methods are often used. Similar to others, we measured the SAB thickness at its thickest point without including the peribursal fat; some have measured at set distances from nearby landmarks and/or included the peribursal tissue.<sup>22-24,28</sup> Assessment of the SAB thickness and neovessels in different positions also limits direct comparison across studies. While the SAB side-to-side cutoff of 0.3 mm is reasonable based on previously reported MDC data for ultrasound assessment,<sup>23,28</sup> it should be recalled that this was calculated post hoc; clinicians should be cautious in adopting this until confirmed in other athlete populations. As some players were included multiple times from different seasons, we assessed for group differences that may have biased the results. Subgroup analyses examining SAB thickness, neovessel presence, and shoulder complaints revealed only one player who presented twice with complaints and increased side-to-side SAB thickness ( $\geq 0.3$  mm) and one player twice with complaints and neovessels. Additional subgroup analyses revealed no group differences in the questionnaire response rate or distribution of responses among players included over multiple seasons. Players were tested and followed systematically for 12 weeks through the use of structured questionnaires; however, other variables such as individual player load were not assessed and may also contribute to complaints.

## 5 | PERSPECTIVE

Players without neovessels and with normal SAB thickness were very unlikely to develop complaints. This stark contrast to players with neovessels or increased SAB thickness, where nearly half of the players developed complaints, is of interest. Position matters — outside hitters and opposites were much more likely to develop shoulder problems. Players with current complaints at baseline presented with greater IR:ER strength ratios; however, neither strength nor IR ROM at baseline was associated with an increased risk of developing future shoulder complaints.

Clinicians with ultrasound machines may want to consider assessing SAB thickness and neovascularity in their overhead

athletes. For all clinicians, it is important to note that thickening of the SAB may be a normal adaptation to the sport. However, a substantial increase in thickening in the dominant arm compared with the non-dominant arm increases the risk of developing shoulder complaints. For players with increased risk, monitoring load and response to load are recommended, in addition to interventions to maximize player health and performance.

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### IRB APPROVAL STATEMENT

This study has been approved by the Anti-Doping Lab Qatar Institutional Review Board (E2013000003).

### CONFLICT OF INTEREST

We have no other conflict of interests.

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