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Infraspinatus strength assessment before and after scapular muscles rehabilitation in professional volleyball players with scapular dyskinesis

Giovanni Merolla, MD[a,*], Elisa De Santis, MS[b], John W. Sperling, MD[c], Fabrizio Campi, MD[a], Paolo Paladini, MD[a], Giuseppe Porcellini, MD[a]

[a]*Unit of Shoulder and Elbow Surgery, D. Cervesi Hospital, Cattolica, Italy*
[b]*ShoulderTech Clinical and Rehabilitative Office, Forlì, Italy*
[c]*Department of Orthopedic Surgery, Mayo Clinic, Rochester, MN, USA*

Hypothesis: This study tested the hypothesis that infraspinatus strength in professional volleyball players can be assessed with the scapula free (infraspinatus strength test, IST) and with the scapula retracted (infraspinatus scapula retraction test, ISRT) before and after scapular musculature training.
Materials and methods: A prospective study was performed in 31 professional volleyball players. Isometric strength (kg) of the infraspinatus with IST and with ISRT was recorded by a handheld dynamometer and compared with the values found after 3 and 6 months of rehabilitation. Magnetic resonance imaging was performed to exclude articular and cuff pathology. Pain scores were assessed using a visual analog scale.
Results: The mean increase in the force values of IST was statistically significant after 3 months ($P < .01$) and 6 months ($P < .001$) of rehabilitation. The mean difference between IST and ISRT decreased from 4.72 $\pm$ 0.007 before rehabilitation to 1.2 $\pm$ 0.26 at 3 months and to 0.4 $\pm$ 0.006 at 6 months. The mean score for pain was 2.4 $\pm$ 1.8 at 3 months and 2.6 $\pm$ 1.4 at 6 months.
Discussion: Acquired scapular dyskinesis in overhead athletes can lead to the rotator cuff weakness. Inhibition due to pain and the negative biomechanic effect of scapular dyskinesis results in specific infraspinatus dysfunction that arise with the ISRT.
Conclusions: ISRT is practical and consistent to assess the infraspinatus strength in overhead athletes with scapular dyskinesis. A functional rehabilitation protocol, designed to restore scapular muscles balance and shoulder mobility, is essential in the training program to prevent shoulder dysfunction and improve sports performance.
Level of evidence: Level IV, Case Series, Treatment Study.

Keywords: Shoulder; infraspinatus strength; scapula; functional rehabilitation

Shoulder pain due to dysfunction of the rotator cuff is a common problem in competitive overhead athletes.[18] Shoulder abduction greater than 90° requires balanced and coordinated activity of the scapular-stabilizing muscles to maintain the ‘‘gliding’’ mechanism that allows the concave anterior surface of the scapula to move on the convex posterolateral surface of the thoracic cage (scapulohumeral rhythm).[20,24] When dysfunction or fatigue of

*Reprint requests: Giovanni Merolla, MD, Unit of Shoulder and Elbow Surgery, ‘‘D. Cervesi’’ Hospital, L.V Beethowen 46, code: 47841, Cattolica (RN), Italy.

E-mail address: gmerolla@shouldertech.it (G. Merolla).

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the scapula stabilizers alter or interrupt scapulohumeral rhythm, shoulder dysfunction occurs with an associated decrease in rotator cuff strength.

Kibler et al[25] exploring the reasons for supraspinatus weakness and described the role of intrinsic factors (injury, disuse atrophy) to create an absolute weakness with respect to the extrinsic factors, such as an unstable base of origin, implicated in the apparent weakness. Other researchers[40,42] reported that the inability to retract the scapula induces a negative biomechanical effect on the shoulder girdle, including narrowing of the acromiohumeral space, a reduced impingement-free arc of elevation, and lower isometric elevation strength. Abnormal scapular motion and the inhibition due to pain[25] linked to the clinical signs of impingement[6] can influence rotator cuff strength.

We hypothesized that inhibition due to pain associated with scapular dyskinesis induces infraspinatus weakness that can be clinically demonstrated by testing the infraspinatus strength with the scapula free (infraspinatus strength test, IST) and with the scapula retracted (infraspinatus scapula retraction test, ISRT). Isometric strength of the infraspinatus was recorded in 31 volleyball players with scapular dyskinesis at baseline and compared with the values found after 3 and 6 months of rehabilitation.

Figure 1 Type I scapular dyskinesis.

Figure 2 Type II scapular dyskinesis.

Materials and methods

Because all participating athletes followed a ‘‘standard of care’’ for their rehabilitation program, this study did not undergo Institutional Review Board approval. All patients consented to voluntarily take part in the study.

Study population

From April 2006 to January 2009, 59 volleyball players complaining of shoulder pain during their sports activity were examined at our rehabilitative office. Magnetic resonance imaging (MRI) was performed in all cases to assess glenoid labrum, ligaments, and rotator cuff (RC) tendons. We found labral injuries in 8 (13.6%), partial supraspinatus tears in 16 (27.1%), and complete supraspinatus tears in 4 (6.8%).

The study enrolled 31 athletes (22 men, 9 women; mean age, 22 $\pm$ 2.5 years), without MRI evidence of articular and cuff tears but with pain and infraspinatus weakness, who were categorized as ‘‘inhibition due to pain’’ athletes. The dominant arm was right in 26 and left in 5, their height was 189 $\pm$ 5.2 cm, weight was 78 $\pm$ 6.4 kg, and playing experience was 7 $\pm$ 2.5 years. All individuals answered a detailed questionnaire on their training program, hours a week spent playing volleyball, and onset of symptoms (years).

Testing technique

Before the testing began, scapular dyskinesis patterns were evaluated and classified according to the scale reported by Kibler et al.[26] Dyskinesis was type I (Figure 1) in 26 athletes (84%) and type II (Figure 2) in 5 (16%). None of the participants had type III dyskinesis or type IV symmetric scapular motion. Testing was performed with the patient standing and the arm adducted, shoulder in neutral rotation, and elbow flexed at 90°.

The IST was administered according to the criteria previously reported[16,28] to assess infraspinatus strength (Figure 3). The ISRT was performed with the examiner behind the patient, using 1 hand to manually retract the scapula, with the other hand offering resistance to the external rotation force applied by the patient (Figure 4). An alternative ISRT can be done by 2 examiners: the first stands in front of patient to assess infraspinatus strength and the second is behind to keep the scapula manually retracted. Quantitative assessment of maximum infraspinatus strength (kg) after a voluntary isometric contraction was registered by a handheld dynamometer (Lafayette Instruments, Lafayette, IN; Figure 5).

Rehabilitation program

The rehabilitation program continued for 6 months and focused on the restoration of control and balance of the scapular muscles.[36] In

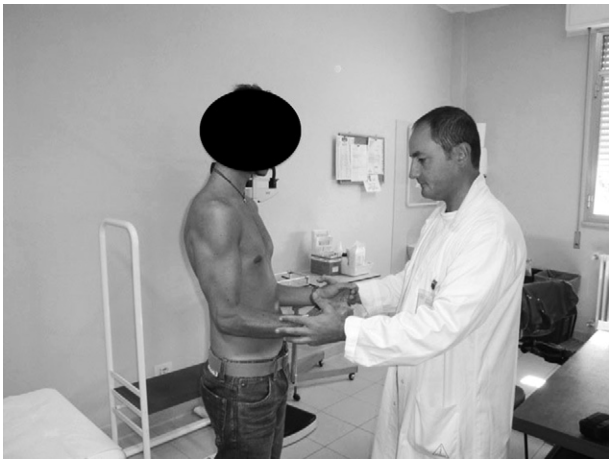

Figure 3 Infraspinatus strength is clinically assessed using the infraspinatus strength test according to Leroux et al.[28]

Figure 4 Infraspinatus strength is clinically assessed with the infraspinatus scapula retraction test.

particular, on the basis of recent research findings that the upper trapezius (UT) had higher activation with a decreased control in the lower trapezius (LT), middle trapezius (MT) and serratus anterior (SA),[9] our working protocol was designed to obtain balance ratios for UT/LT, UT/MT (Figure 6), and UT/SA (Figure 7). Active exercises for MT are associated with reinforcement of the rhomboid muscles (Figure 8).

Acceleration, deceleration, and follow-through phases of striking in volleyball require that the rotator cuff muscles act eccentrically to compress the humeral head.[35] During spiking and serving, the supraspinatus, infraspinatus, and teres minor muscles eccentrically resist translation and assist in deceleration of the moving limb.[10,35] As a consequence, this increases the stress placed on the passive stabilizer of the shoulder,[10,35] leading to a posterior shoulder soft-tissue tightness similarly to the throwing athletes.[5] Passive and ballistic stretching in several directions is routinely recommended[19,27] in overhead athletes; therefore, posterior soft-tissue stretching[2] (Figure 9) accompanies open kinetic chain exercises for shoulder girdle[5] to act on posterior structural changes and minimize the effects on shoulder internal rotation (IR; Figure 10, *A*).

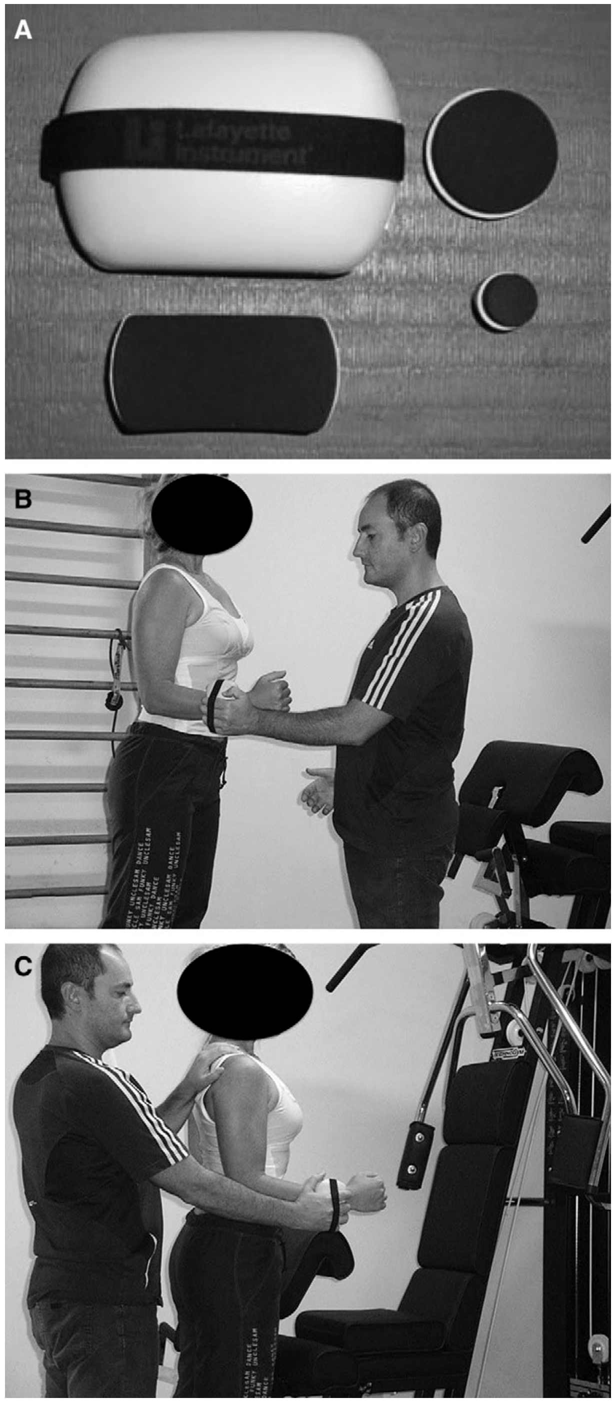

Figure 5 **(A)** A handheld dynamometer (Lafayette Instruments, Lafayette, IN) is used for strength measurement. **(B)** Infraspinatus strength is registered during maximum isometric contraction. **(C)** Infraspinatus strength is registered with the scapula retracted during maximum isometric contraction.

Data analysis

Strength values (mean ± standard deviation) of the infraspinatus were recorded at 3 and 6 months of follow-up by 2 independent observers. We used a paired *t* test for statistical analysis, with significance at 1% ($\alpha = 0.01$).[1] The pain score was assessed with

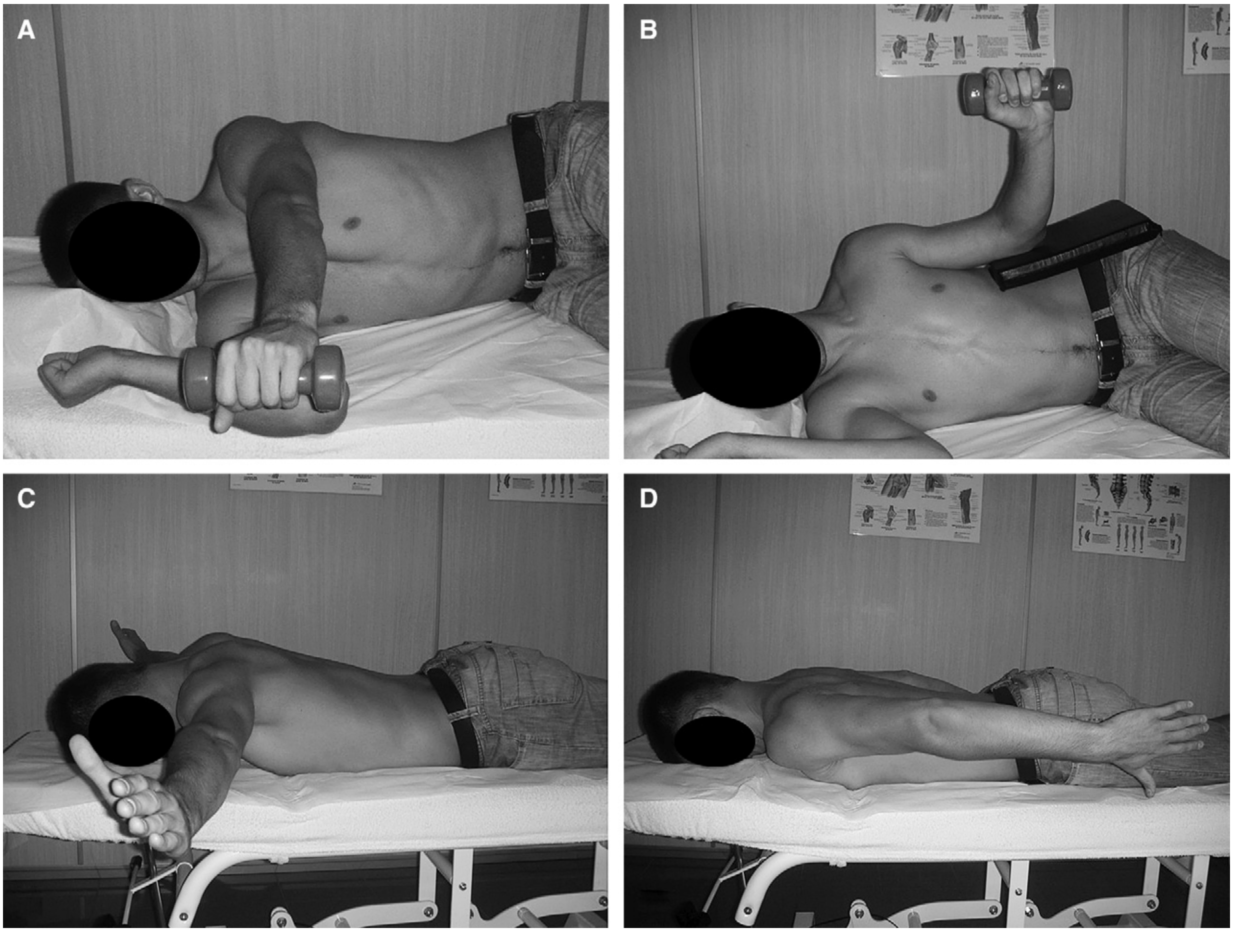

Figure 6 Exercises we selected as essential for a balance of muscle activity of the upper (UT), lower (LT), and middle trapezius (MT) included **(A)** lateral decubitus forward flexion, **(B)** lateral decubitus external rotation, **(C)** horizontal abduction with the arm in external rotation, and **(D)** extension in the prone position. Exercises shown in *A, B,* and *C* restore the UT/LT ratio, and exercises shown in *A, B,* and *D* are optimal to restore UT/MT muscle imbalance.[8]

a visual analog scale (VAS) and reported as mean ± standard deviation.[34] The variability of the 2 independent observations was calculated by the Bravais-Pearson correlation coefficient.

Results

Participants spent a mean 7.8 ± 1.4 hours a week playing volleyball. The dominant arm was involved in 29 (93.5%). The patients reported the onset of symptoms a mean of 4.3 ± 1.2 years before presentation. MRI excluded rotator cuff tears or other shoulder injuries in all athletes (Figure 11). The infraspinatus strength values collected with IST and ISRT are reported in Table I. The mean increase in the IST force was significant at 3 months (3.6 ± 0.09; $P < .01$) and at 6 months (4.3 ± 0.02; $P < .001$) of rehabilitation. When IST and ISRT force values were compared, the mean difference decreased from 4.7 ± 0.007 before rehabilitation to 1.2 ± 0.26 at 3 months ($P < .01$) and to 0.4 ± 0.006 at 6 months ($P < .001$). An increase of glenohumeral IR was observed (Figure 10, *B*), but no data are available to support these findings. Pain scores decreased from 7.2 ± 1.3 to 2.4 ± 1.8 at 3 months ($P < .01$) and to 2.6 ± 1.4 at 6 months ($P < .01$; Figure12). The Pearson correlation coefficient was close to 1 (95% confidence interval, 0.91234-0.91635), which indicated an excellent interobserver correlation.

Discussion

Several studies have reported the important contribution of proper scapular positioning for normal shoulder function.[8,26,31,40-42,44] Abnormal scapular motion observed in competitive overhead athletes is associated with excessive joint distraction force that may contribute to the posterior structural change and induce negative effects on shoulder IR.[5] The need of a retracted scapula to have a stable base of support for the rotator cuff muscles is confirmed by recent research[39] in which scapular protraction was correlated with reduced force-generating capabilities for the internal and external rotators. Neuromuscular control around the scapula depends on a balance protraction-retraction ratio, and the timing of scapular muscles recruitment is essential for scapular stability during shoulder motion.[5,23,47]

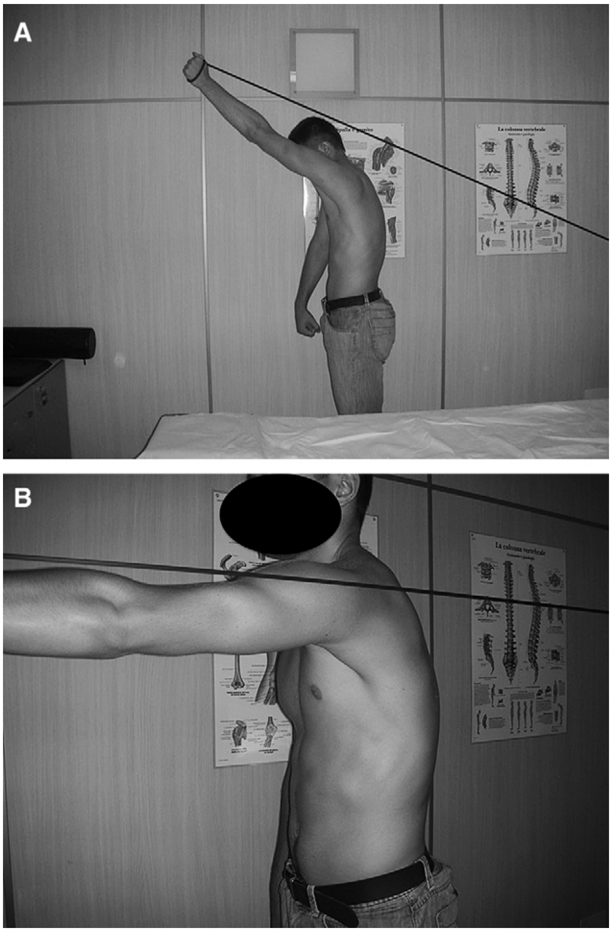

Figure 7 Elastic resistance exercises for the serratus anterior are shown with the arm in **(A)** maximum flexion and **(B)** medium flexion.

Muscular activation patterns are compromised when the rotator cuff muscles are placed in a shortened position on their length-tension curves.[9] Scapulothoracic dysfunction[9,37] following this muscle imbalance increases the demand on the rotator cuff musculature that is not capable to generate the maximum force, and the secondary result is rotator cuff weakness.[15,21]

Some authors have investigated external rotation strength in the pitcher's throwing shoulder, demonstrating weaker external rotation strength compared with the nonthrowing shoulder,[4,7,45,46] but none have emphasized the role of the scapula in the muscle weakness. The effect of scapular protraction on isometric rotation strength in healthy volunteers was measured by Smith et al[39] to highlight that most shoulder disorders result from cumulative, microtraumatic overuse injuries to the rotator cuff and shoulder soft tissues.[17] Kibler et al,[25] in a very interesting study, described the difference of supraspinatus strength by comparing the empty can position with the SRT in patients with and without shoulder injuries and reported significantly greater outputs with the SRT than with the empty can position.

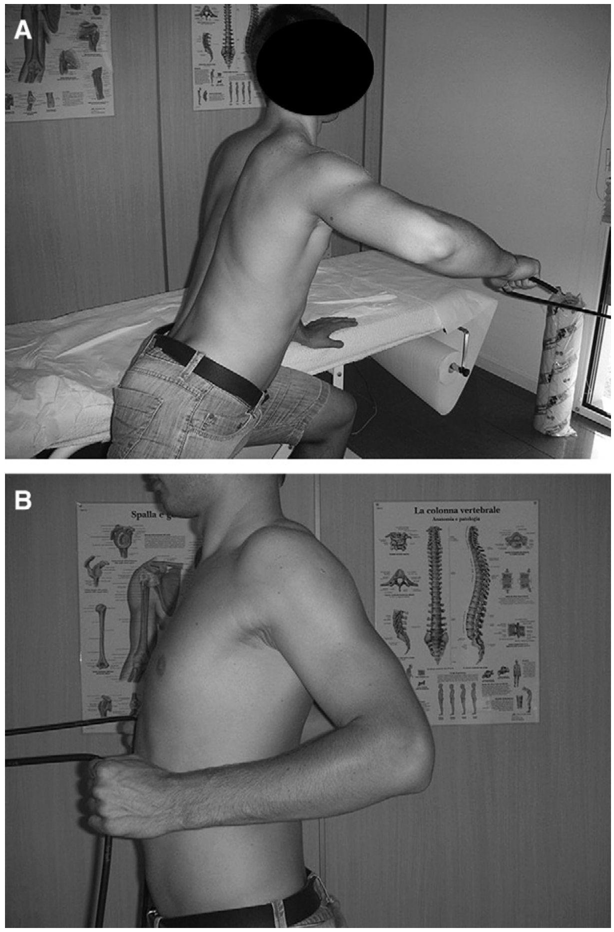

Figure 8 **(A and B)** Elastic resistance exercises are shown for the rhomboid muscles.

Figure 9 Side-lying posterior capsular stretching.

In the current study, we report our experience with a practical and consistent test that allows clinicians to evaluate patients diagnosed with infraspinatus weakness associated with scapular dyskinesis and direct them toward a specific rehabilitation protocol designed to restore

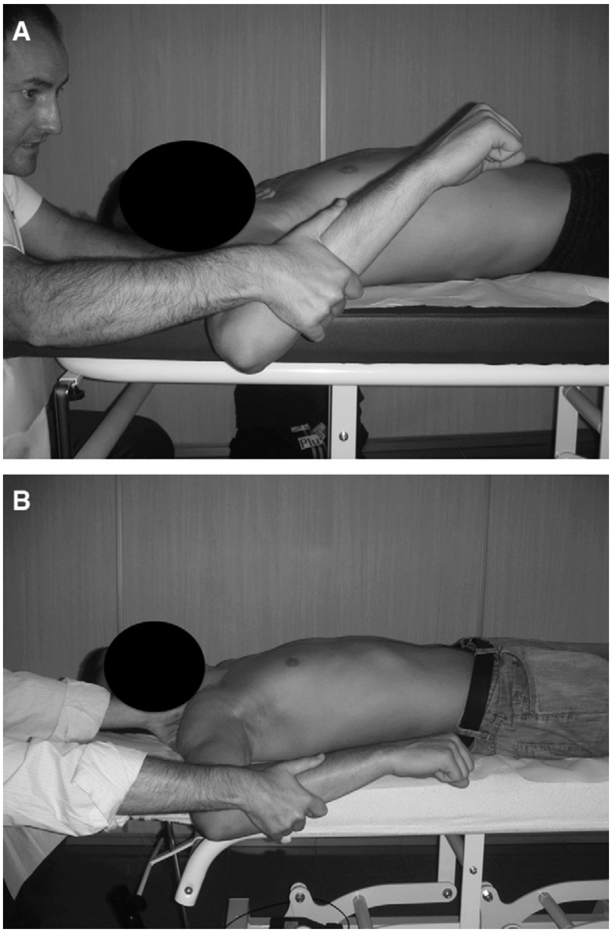

Figure 10 Internal rotation is shown **(A)** before the rehabilitation and **(B)** at the 6-month rehabilitative follow-up.

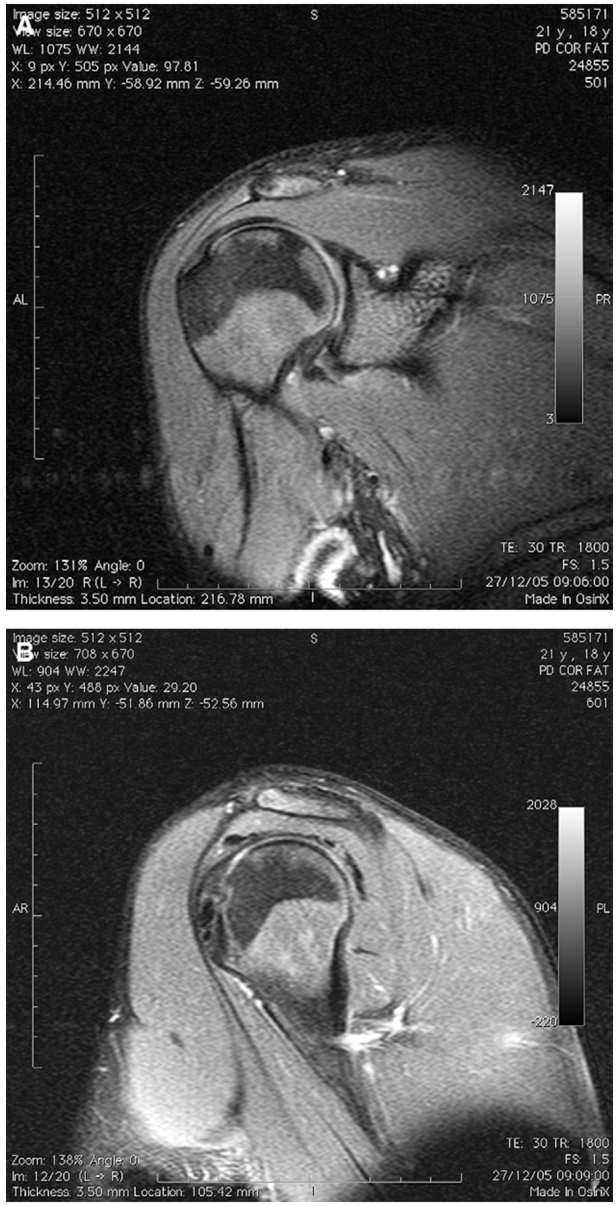

Figure 11 T2-weighted **(A)** oblique coronal and **(B)** oblique sagittal magnetic resonance images show a preserved acromiohumeral interval and anatomic integrity of the rotator cuff in a 19-year-old patient.

balance and recruitment of the scapular muscles. To initiate the best functional protocol, the role of the scapula in the coordination of shoulder girdle movement must be clearly identified. This role can be summarized in three points: (1) maintain dynamic stability and control glenohumeral joint mobility,[33] (2) the scapula as the basis for muscle attachment,[12,23] and (3) the scapula as the link in the proximal-to-distal transfer of energy for the appropriate shoulder positioning.[13,22]

Scapulothoracic translation can occur as[30] (1) upward and downward translation on the thoracic wall (rotation around a horizontal axis perpendicular to the plane of the scapula) or (2) retraction and protraction around the rounded thorax (internal and external rotation around a vertical axis through to the plane of the scapula). An anterior and posterior scapular tilt (around a horizontal axis in the plane of the scapula) is associated with the internal and external rotation around the thoracic cage.[30] The acromioclavicular joint internally rotates and the sternoclavicular joint posteriorly[29] retracts during scapular internal and external rotation. The acromioclavicular and sternoclavicular joints contribute to the scapular upward rotation that is followed by acromion upward rotation. Abnormal increases in scapular protraction induce loss of acromial upward rotation and concomitant coracohumeral arch compression.[8,23]

The scapular stabilizer musculature (MT and rhomboids) attaches on the medial border of the scapula, and through synergistic contractions and force couples of the UT and LT[3] together with the rhomboid and SA muscles,[11,14] controls glenoid position as a stable ‘‘socket’’ for the humeral head. Finally, the scapula is considered the pivot point to regulate and transfer efficiently the high energy generated from the lower limbs (legs and trunk) to the upper limb (arms and hands).[13,24]

Table I Infraspinatus strength test and infraspinatus scapula retraction test force values registered before and after rehabilitation

Variable	Force values, mean ± SD kg	
	IST	ISRT
Before rehabilitation	10.1 ± 0.30	14.8 ± 0.31
3 months	13.7 ± 0.39	14.9 ± 0.12
6 months	14.4 ± 0.28	14.8 ± 0.26

ISRT, infraspinatus scapula retraction test; *IST,* infraspinatus strength test; *SD,* standard deviation.

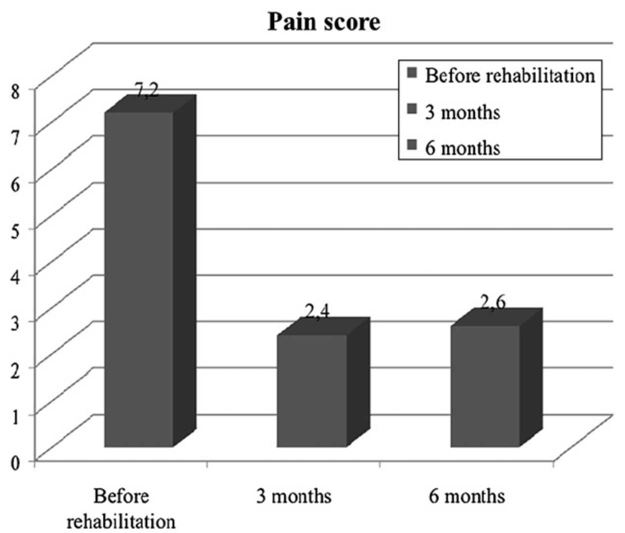

Figure 12 Values of pain scores are shown before and after rehabilitation.

These considerations have guided our plan of reduction for a selective recruitment of weaker scapular muscles and reduced activity in overused musculature that result in lower muscle imbalance. To obtain the aforementioned muscle balance, we included exercises for the LT and MT with minimal activation of the UT, which is generally overused; the work on the SA was important to have a good balance ratio with the UT. Analyzing our results, we observed that infraspinatus strength values of IST increased from 10.1 to 13.7 at 3 months and to 14.4 at 6 months, whereas no significant difference were found for ISRT at 3 months ($P = .31$) and 6 months ($P = .29$). A decrease in pain from 4.8 at 3 month to 4.6 at 6 months was consistent with the recovery of rotator cuff strength.

Several studies have described the relationship between abnormal biomechanics and overuse injuries about the shoulder girdle and alteration of scapular kinesis.[24,26,32,38,39,43] Pain decrease and infraspinatus strength recovery observed in these athletes after the reinforcement of the scapular musculature suggest the role of the scapular position to maintain the optimal length-tension relationship of the rotator cuff muscles.[39]

Some weak points can be identified in our study. Patients referred satisfactory shoulder IR, and our clinical findings suggested an increase of IR after the rehabilitation, but IR was not quantified and therefore represents a limitation. Similarly, data are lacking concerning the position of the scapula before and after the rehabilitation. A further point of discussion could be the analysis of the activation-sequencing patterns of the muscle that stabilize the scapula, but these arguments are beyond the scope of the current article that highlights the clinical relevance of the scapular retraction maneuver in the assessment of infraspinatus strength. Inhibition due to pain, as part of the symptoms associated with impingement in these athletes and the negative biomechanic effects of altered scapular kinesis that provide an unstable base of support for rotator cuff muscles, result in specific infraspinatus dysfunction that arises with ISRT.

The application of ISRT in clinical practice should be considered in healthy individuals and symptomatic individuals with scapular dyskinesis. In healthy individuals, equivalent values of the infraspinatus strength are seen in both tests, whereas in symptomatic individuals, a significant difference of IST respect to ISRT can be appreciated. In the athletes examined for this study, the difference in the ISRT values decreased as their pain decreased.

Conclusion

Despite the mentioned limitations, this study seemed to support our idea that acquired scapular dyskinesis in overhead athletes should be seen as the weak point in the chain of events that lead to rotator cuff weakness. Unfortunately, this is sometimes misunderstood or underestimated by those caring for athletes.

Inhibition due to pain and the negative biomechanic effects of scapular dyskinesis that provide an unstable base of support for the rotator cuff muscles results in specific infraspinatus dysfunction that arises with the ISRT. Restoration of scapular muscular balance and recovery of shoulder mobility should be considered as essential part of the training program, which should start early in the athlete's career to prevent shoulder dysfunction and improve sports performance.

Disclaimer

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