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SHOULDER

Evidence-based rehabilitation of athletes with glenohumeral instability

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Abstract
Purpose To give an overview of current knowledge and guidelines with respect to evidence-based rehabilitation of athletes with glenohumeral instability.
Methods This narrative review combines scientific evidence with clinical guidelines based on the current literature to highlight the different components of the rehabilitation of glenohumeral instability.
Results Depending on the specific characteristics of the instability pattern, the severity, recurrence, and direction, the therapeutic approach may be adapted to the needs and demands of the athlete. In general, attention should go to (1) restoration of rotator cuff strength and inter-muscular balance, focusing on the eccentric capacity of the external rotators, (2) normalization of rotational range of motion with special attention to the internal rotation ROM, (3) optimization of the flexibility and muscle performance of the scapular muscles, and (4) gradually increasing the functional sport-specific load on the shoulder girdle. The functional kinetic chain should be implemented throughout all stages of the rehabilitation program. Return to play should be based on subjective assessment as well as objective measurements of ROM, strength, and function.
Conclusions This paper summarizes evidence-based guidelines for treatment of glenohumeral instability. These guidelines may assist the clinician in the prevention and rehabilitation of the overhead athlete.
Level of evidence Expert opinion, Level V.

Keywords Shoulder instability · Rehabilitation · Exercise

Introduction

The shoulder of the overhead athlete is susceptible to traumatic injuries such as dislocations and soft tissue injuries, in particular in collision and contact sports. However, many injuries result from repetitive overuse mechanisms, due to overload, aberrant overhead throwing biomechanics and dysfunctional adaptations to the sport. These may lead to chronic symptoms like functional instability and secondary impingement [13]. Moreover, the shoulder is predisposed to athletic injury because of the large amount of mobility of the glenohumeral joint, allowing powerful throwing and smashing, but putting the shoulder at risk for injury due to the inherently poor glenohumeral stability [68].

Shoulder instability can be classified based on the frequency (first time vs. recurrent), aetiology (traumatic, non-traumatic), direction (anterior, posterior, inferior), and severity (subluxation vs. dislocation) [31]. However, in the clinical field, athletes often present with combined patterns of structural as well as functional instability (based on muscle patterning deficiencies), and these factors should rather be seen as a continuum [27].

From a clinical perspective, it is important to determine the injury mechanism, in particular after a traumatic onset. Powerful external rotation–abduction increases the likelihood of neurovascular damage with an anterior dislocation. In chronic shoulder pain, it should be determined how the

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symptoms started. Did they result from an initial trauma, or was there a rather gradual onset? The symptoms should be interpreted in relation to the load on the shoulder (timing in the season, position played in team sports, etc.) Recurrent functional shoulder instability and impingement symptoms are often related to fatigue, aberrant sporting biomechanics, or a sudden increase in training or competition volume [68].

During the clinical examination, the clinician should identify the degree and direction of the instability and look for concomitant pathologies like rotator cuff tendinopathy or tears, labral pathology, SLAP lesions, and involvement of the biceps in the symptoms [11]. In addition, a thorough screening of the cervical and thoracic spine, as well as assessment of mobility, strength and stability of the lower quadrant, should be performed [64].

From a functional perspective, specific deficits should be assessed at all levels of the kinetic chain, from the shoulder up to more proximal links. On the glenohumeral level, proprioception, rotator cuff strength and motor control, and rotational range of motion should be examined. Special attention should go to the glenohumeral internal rotation range of motion deficit (GIRD), total range of motion (TROM), and eccentric strength of the decelerator mechanism—external rotators [12, 28]. Scapular flexibility as well as muscle performance should be observed and explored [17]. Core stability, ROM, and strength of the hips should be screened. Functional tests for upper (for instance, seated medicine ball throw and Y-balance test) [63, 66] and lower extremities (for instance, jump height and step down test) [46] should be implemented.

Evidence-based practice should be the integration of the best available research evidence, with clinical expertise and patient values [26]. Therefore, exercise prescription for the individual athlete should be based on a clinical reasoning process during the physical examination, as well as on general guidelines for rehabilitation, and the specific characteristics and demands of the sport. In addition, exercises should be selected based on their assumed effect (for instance, muscle activation patterns based on EMG studies) and scientific outcome studies of specific programs (for instance, eccentric training programs and specific posterior shoulder stretching programs). In the following paragraphs, we will briefly describe some key factors that should be considered when designing a rehabilitation program, based on the above-mentioned principles. Glenohumeral, scapulothoracic as well as kinetic chain components will be discussed. This combined approach offers new insights into the rehabilitation of glenohumeral instability in the overhead athlete.

Exercise treatment focussing on the glenohumeral joint

Neuromuscular control and strength training of the rotator cuff

Several studies confirm the lack of adequate muscle activity of the local stabilizers in patients with shoulder pain. Mainly the rotator cuff muscles show deficiencies in neuromuscular control, accurate timing of muscle activation, and strength [23]. Therefore, the first stage in rehabilitation should comprise encouragement of local muscle control, by teaching the patient how to consciously co-contract the rotator cuff (with palpation, EMG feedback, local proprioceptive feedback, etc.) or by stimulating cuff activity through rhythmic stabilization exercises [68].

Once neuromuscular control is restored, strengthening exercises for the rotator cuff may be included. Based on EMG studies [4, 48], elevation in the scapular plane, external rotation, and horizontal abduction with external rotation may be preferred to activate the supraspinatus, infraspinatus, and teres minor. There is no consensus regarding the role of internal rotation exercises activating the subscapularis. Based on the study of Townsend et al. [58], the exercises with the highest subscapularis activity are elevation in the scapular plane. There is no specific exercise highlighting activity in the subscapularis, and during internal rotation, mainly the prime movers like the pectoralis major and latissimus dorsi seem to be activated.

In case chronic shoulder instability is associated with rotator cuff tendinopathy, eccentric exercises may be included [37]. Evidence on structural changes in the rotator cuff tendons after eccentric training is currently lacking [7], but clinical improvement was established [25, 37]. Exercises may be performed in a controlled slow manner, avoiding the concentric phase to allow maximal loading of the eccentric phase, or in a more plyometric way. Moreover, it needs to be recognized that the rotator cuff is activated in an eccentric mode during sports activity, which strengthens the argument to include eccentric training in rehabilitation of the overhead athlete with sport-related instability and rotator cuff dysfunction. In addition, neuromuscular control and appropriate strength in the scapulothoracic joint are necessary for a beneficial effect of these exercises, in view of the recognized scapular muscle dysfunction in shoulder patients [54].

Restoring glenohumeral range of motion

Posterior shoulder stiffness is probably the most common adaptation seen at the dominant side of overhead athletes of multiple sports disciplines [5]. Combined with the typical

acquired laxity of the anterior capsulolabral complex, this adaptation may lead to excessive anterior head translations during overhead throwing and subsequently to functional instability. Posterior shoulder stiffness manifests clinically as decreased glenohumeral cross-body adduction and internal rotation mobility and is believed to be the result of both capsular tightness and muscular contracture. It is hypothesized that the cumulative loads onto the posterior shoulder during the deceleration phase of the throwing motion cause microtrauma and scarring of these soft tissues [5]. Posterior shoulder stiffness therefore has been suggested to be a causative or perpetuating factor in shoulder impingement and labral pathology [8].

Given the evidenced impact of posterior shoulder tightness on shoulder kinematics, increasing posterior shoulder flexibility is advisory when mobility deficits exceed the limits associated with increased injury risk. Both the cross-body stretch and the sleeper stretch can be recommended to decrease posterior shoulder tightness [40]. It was shown that a 6-week daily sleeper stretch program (3 reps of 30 s) is able to significantly increase the acromiohumeral distance in the dominant shoulder of healthy overhead athletes with GIRD [36]. Additional joint mobilization performed by a physiotherapist has a small advantage over a home stretching program alone [38]. No difference in mobility gain was seen after angular (sleeper stretch and horizontal adduction stretch) and non-angular (dorsal and caudal humeral head glides) joint mobilization by a physiotherapist [9]. Muscle energy techniques (hold-relax) during the sleeper stretch and the horizontal adduction stretch have proven useful to immediately increase internal rotation range of motion [43]. Two studies [9, 59] showed symptom relief after a stretching program in a population of overhead athletes with impingement-related shoulder pain.

Progressive exercise training for overhead athletes with SLAP lesions and biceps-related pathology

Biceps-related pathological disorders are a common cause of shoulder pain and disability and can result in limited athletic performance. In the rehabilitation of pathological changes of the long head of the biceps and SLAP lesions, caution is warranted regarding muscle activation of the biceps in view of tissue protection and healing. Graded progressive loading on the muscle is crucial during the rehabilitation process. In a recent study, a progressive exercise program was presented, based on the EMG activity of the biceps [10]. Exercises targeting the trapezius resulted in less loads on the biceps compared with exercises for the serratus anterior. In addition, exercises with an internal rotation component showed low activity in the biceps. In general, the exercises meant to target the biceps (such as performing forward flexion with the forearm in supination and the shoulder externally rotated) showed the highest levels of activity. In the advanced stages of rehabilitation, higher load on the biceps is needed to increase its strength in order to prepare the athlete to return to sport, by performing eccentric deceleration exercises in throwers or pull-up exercises in gymnasts, climbers, or pole vaulters.

Exercise treatment focusing on the scapulothoracic joint

Full upper limb elevation requires 3-dimensional rotation of the scapula and the clavicula as coupled movements into upward rotation, posterior tilting and adequate internal or external rotation, depending on the plane of the moving humerus. This movement pattern ensures that the coracoacromial arch is removed from the path of the greater tuberosity of the elevating humerus, thus avoiding potential impingement. Scapular control also enhances joint stability at greater than 90° of abduction by placing the glenoid fossa under the humeral head, where stability is assisted by the action of the deltoid muscle. In view of the limited ligamentous constraints between the scapula and the thoracic wall, the scapulothoracic muscles play the most important role in dynamic scapular stability.

There is a body of evidence suggesting scapular dyskinesis in patients suffering from shoulder pain, although the cause–consequence relationship is still under debate [54]. Scapular dyskinesis has been found to be related to shoulder instability, impingement, and stiff shoulders and is identified as a primary risk factor for shoulder injury in rugby and handball players [8, 29].

Once deficits and imbalances in scapular behaviour are assessed, an intervention program to restore flexibility and muscle performance needs to be installed. Recently, a science-based clinical reasoning algorithm was published guiding the clinician into the different steps and progressions [17]. The main goal is (1) to restore flexibility of the surrounding soft tissue of the scapula, in particular pectoralis minor, levator scapulae, rhomboid and posterior shoulder structures, and (2) to increase scapular muscle performance around the scapula, focusing on either muscle control and inter- and intramuscular coordination or muscle strength and balance.

Management of flexibility deficits in the scapular muscles

Several stretching techniques have been described to increase pectoralis minor length. Superior effects of the "unilateral corner stretch" (performing passive horizontal abduction with the shoulder in 90° of abduction and external rotation) over "sitting manual stretching" (in which the

therapist performs scapular retraction with the shoulder in a neutral position) and "supine manual stretch" (similar to the unilateral corner stretch, but performed by the therapist with the patient in a supine position) were established in a study on healthy subjects [6]. Lee et al. [32] demonstrated superior effects of a combined stretching and active exercise program on pectoralis minor length compared to isolated exercises alone for scapular control in subjects with round shoulder posture. However, from a clinical perspective, these stretches (with the exception of the "sitting manual stretching") put the athlete's shoulder into a position, possibly causing pain and discomfort in case of instability. Therefore, in clinical practice, the pectoralis minor might be stretched performing passive retraction and posterior tilting of the scapula with the shoulder in a neutral or small elevation position and slight external rotation [23]. In addition, soft tissue techniques directly on the pectoralis minor might result in a muscular relaxation.

Exercises for scapular muscle control, muscle balance, and muscle strength

In the early stage of scapular training, conscious muscle control of the scapular muscles may be necessary to improve proprioception and to normalize scapular resting position. In order to selectively activate the scapular stabilizers, the "scapular orientation exercise" has been described [44]. The use of neuromuscular electrical stimulation may be helpful in this stage, resulting in better co-contraction between the muscles targeted [3].

In the intermediate phase of scapular rehabilitation, exercises may be selected based on the specific deficits and demands of the patient [17]. Specific exercises are described for activation of the serratus anterior [21, 35], lower and middle trapezius [14, 21], and upper trapezius [21, 47]. In particular, in case of combined flexibility deficits, exercises should be selected not only based on high activity in the targeted muscle group, but also based on low activity in the overactive muscles. For instance, performing elevation with an external component or as a "wall slide" may change relative muscle activity in the scapular muscles. Shrugging with the arms in full elevation may involve more upper trapezius and lesser levator scapulae activity.

Several studies have examined the effectiveness of a scapula-based rehabilitation program [19, 25, 41, 55]. In general, these studies show better results regarding functional outcome, strength and patient satisfaction, if a scapular approach is implemented in the treatment protocol.

In the third stage of scapular rehabilitation, the treatment goal is to exercise advanced scapular muscle control and strength during sport-specific movements. Special attention is given to integration of the kinetic chain into the exercise program, implementation of sport-specific demands by performing plyometric exercises and eccentric exercises. Scapular control should be automatic and integrated into all sport-specific exercises.

Integration of the functional kinetic chain in shoulder stabilization exercises

It is important to implement the kinetic chain early in the rehabilitation process. While the shoulder is recovering from the injury or surgery, leg and trunk exercises can be prescribed so that when the shoulder is ready for rehabilitation, the base of the kinetic chain is also ready for linked activity and functional movement patterns.

The kinetic chain in which the athlete functions is highly sport specific, and needs to be reconsidered for every athlete. In ground-based sports, like baseball, tennis or cricket, all of the activities of the shoulder work within a kinetic chain linkage from the ground through to the trunk, mostly in a diagonal pattern. These athletes benefit from diagonal patterns in a closed chain for the lower extremities, for instance shifting body weight to the contralateral leg during the exercise or performing movements in unilateral stance on the contralateral leg. In addition, research has shown that performing shoulder exercises (rowing) standing on the contralateral leg enhances scapular muscle activity [20]. Volleyball players, however, load their shoulder the most during smashing, when their feet are off the ground. They should train the smashing and decelerating capacity of their shoulders with minimal input from the ground, for instance on an unstable surface. Sports like gymnastics and swimming have totally different movement patterns and thus different demands from their kinetic chain. Gymnasts should train in hanging or high-load closed chain positions mimicking their sport-specific positions. Swimmers should focus on endurance in a concentric manner in a prone and supine position. Tennis (for the 2-handed backhand), hockey, and golf players should additionally pay attention to movements using both hands. Athletes who have to be able to "fall" (diving in volleyball, goal keepers in soccer, etc.) should be trained to do so, for instance using sliding boards.

It is important to correct any inflexibilities of the hamstrings, hip, and trunk; weakness or imbalances of the rotators of the trunk, flexors, and extensors of the trunk and hip; and any subclinical adaptations of stance patterns or gait pattern.

Special considerations after shoulder dislocations

In general, after a first-time acute shoulder dislocation, the shoulder is immobilized in a sling for a short period

(depending on the physician's preference and the patient's compliance), after which the rehabilitation program may be started [68]. However, in case of recurrent instability, participation in collision and contact sports, or elite sports performance, surgical stabilization is preferred using a Bankart or a Latarjet procedure [51].

After a surgical procedure, the shoulder is immobilized for approximately 4 weeks, and only active-assisted exercises within the safe zone are allowed. Scapular corrective exercises may be performed, even during the immobilization period. Glenohumeral mobilization exercises and proprioceptive training are allowed after 4 weeks, with the aim of full restoration of ROM after 2 months. However, forced passive external rotation should be avoided the first 3 months after surgery, and very gradually implemented. Stabilization exercises and rotator cuff strengthening can be performed from 2 months post-operatively. Return to sports is provided 4–6 months after surgery, depending on the sports. The post-operative rehabilitation after a Latarjet procedure is similar to that after a Bankart procedure; however, often someway accelerated.

During the rehabilitation, attention goes progressively to (1) improving local proprioceptive muscle control of the rotator cuff, (2) low-load closed chain exercises (wall slides) [62], followed by (3) closed chain exercises with increasing load (prone bridging, side bridging) [60], and (4) graded progressive functional open chain exercise program, consisting of rotational movements, scapular muscle training, and functional exercises.

Although general guidelines and stages are described in the literature, it is important to determine the progression based on the individual athlete, for instance based on the ROM achieved, the subjective feeling of safety, the confidence of the athlete in the more challenging positions and movements and the instructions of the surgeon. A recent qualitative investigation of return to sport after arthroscopic Bankart repair revealed that fear of reinjury, mood, social support and self-motivation greatly influenced the return to sport [57].

Special considerations for the overhead athlete with multidirectional instability (MDI)

While the majority of overhead athletes exhibit symptoms of anterior instability, patients with MDI show symptomatic glenohumeral subluxation or dislocation in more than one direction [24]. There is a general agreement that MDI is the result of repetitive microtrauma imposed on a congenitally lax and redundant joint capsule [24]. MDI is fundamentally a different pathology than unidirectional instability, which is typically the result of a traumatic event imposed on a normal glenohumeral joint. Patients with MDI may present with a variety of symptoms from vague pain and discomfort to frequent dislocations during basic daily activities. MDI is often seen in athletes with high demands on general ROM during their sports performance, like gymnasts and swimmers.

The most commonly recommended treatment for MDI is non-operative with an emphasis on exercise-based management [24, 27]. Surgery to tighten the glenohumeral joint capsule may be indicated in some cases in which the conservative treatment fails [34, 49]; however, the long-term outcomes of these surgical outcomes are still unknown [1]. Rehabilitation consists of scapular exercises (promoting upward rotation) and neuromuscular rotator cuff training. In view of the well-known advantages of closed chain exercises enhancing static stability through joint compression and stimulation of the periarticular mechanoreceptors [33], a progressive exercise program using closed chain exercises may be beneficial to allow muscle training in a more stable environment. Progress may be performed by (1) progressing from static to dynamic exercises and (2) increasing the load (body weight) on the shoulders.

In a recent systematic review on the effect of exercise-based management for MDI, it was concluded that exercise appears to be beneficial for patients with atraumatic MDI; however, the large heterogeneity and low quality of the included studies, as well as the poor definition of the exercise protocols, made it very difficult to evaluate its true effects [65].

Return to sports after shoulder instability: Do we have objective criteria?

According to the decision-based return-to-play model, described by Matheson et al. [39], three steps need to be taken prior to full return to sports. In a first step, the health status of the athlete is evaluated, including assessment of symptoms and a battery of analytical and functional tests, for instance strength and flexibility, and throwing performance. Second, the clinician evaluates the participation risk, based on the type of sport, level of competition and ability to protect the shoulder. In a third step, some factors might modify the decision such as the timing in the season, pressure from the athlete or his environment. However, in spite of this science-based model to be implemented into clinical practice, little evidence exists regarding the physical return-to-play criteria of the shoulder after injury. In particular, from a clinical perspective, there is a need for cut-off values to be used as criteria for return to train and return to play. In addition, the clinician needs objective and valid assessment tools applicable on the field or the training area of the athlete. In particular, glenohumeral ROM and strength, scapular position and strength, pectoralis

minor length, and functional performance tests may be of interest.

With respect to ROM, loss of internal range of motion is known to be a risk factor for chronic shoulder pain [8, 53, 67]. There is no consensus in the literature with respect to the cut-off values for internal ROM, ranging from 18° [67] up to 25° [53] depending on the study design and population. Therefore, in view of maximal protection of the athlete, it is advised that side differences in internal rotation ROM should be less than 18°, and the difference in total range of motion should not be more than 5° [67]. The assessment of the ROM into rotation of the shoulder can be measured with a goniometer or an inclinometer and in many positions of the body and the shoulder. A comprehensive reliability study [12] showed high to excellent inter- and intra-tester reliability for a variety of test positions and equipment. Based on the results of this study, no specific procedure can be acknowledged to be superior to another one. However, the clinician has to take into account that large variability exists in the literature regarding shoulder position (for instance, scapular or frontal plane) and the specific method of scapular stabilization (none, hand on shoulder top, or specific fixation of coracoid).

Regarding rotator cuff strength, it is generally recognized that overhead athletes often exhibit sport-specific adaptations leading to a relative decrease in the strength of the external rotators and thus muscular imbalance in the rotator cuff [16, 22, 52]. In general, with respect to cut-off values distinguishing a healthy shoulder from a shoulder at risk, an isokinetic ER/IR ratio of 66 % or an isometric ER/IR ratio of 75–100 % (depending on the testing position [16, 18]) is advised, with a general rotator cuff strength increase of 10 % of the dominant throwing side compared to the non-dominant side. Bak and Magnusson [2] were the first to introduce the functional ratio eccentric ER/concentric IR ratio in the shoulder, distinguishing symptomatic from asymptomatic shoulders. In general, focus has shifted from isometric or concentric to eccentric muscle strength of the rotator cuff. In particular, the eccentric strength of the external rotators is of interest [18, 28]. Johansson et al. [28] demonstrated good to excellent reliability for measuring the eccentric ER strength using a hand-held dynamometer, and Cools et al. [18] found unilateral functional ratios eccER/isomIR varying between 0.97 and 1.31, with differences based on gender and side. In general, from a clinical perspective, the ratio should be at least 1, meaning that the eccentric strength of the ER is equal to the isometric IR strength.

Evidence supporting cut-off values for prevention of injury or return to play after injury with respect to scapular function is scarce. A statement saying that scapular behaviour should be symmetrical in overhead athletes is not supported by research data, on the contrary. In non-injured volleyball, as well as in handball players, asymmetry was found in resting scapular posture [45, 50]. Uhl et al. [61] also reported that the prevalence of scapular dyskinesis was almost identical in subjects with and without shoulder pain, questioning the clinical value of scapular asymmetry. Therefore, clinicians should be aware that some degree of scapular asymmetry may be normal in some athletes. It should not be considered automatically as a pathological sign but rather an adaptation to sports practice and extensive use of upper limb. Based on studies measuring scapular upward rotation [15, 56] (with an inclinometer) and muscle strength [15, 42] (with a HHD), cut-off values for normal scapular position and strength are approximately 60° of upward rotation in full arm elevation, 10 % increased strength on the dominant side in one-handed sports like volleyball, and equal strength on both sides in bilateral sports such as swimming. In particular, the lower trapezius and serratus anterior should receive special attention, since these muscles are shown to be susceptible to weakness in injured athletes [17, 30].

Tightness of the pectoralis minor may be clinically observed by evaluating shoulder position with the patient supine (with more protracted shoulder position in case of short pectoralis minor) and objectively measured by determining the distance between the coracoid process and the fourth rib [6]. When normalized to body height (pectoralis index = pect length/body height), the PMI should not be below 7.65, indicating a short pectoralis minor [6].

Functional performance tests for shoulder function are gaining interest, although not yet fully explored in clinical practice. The seated medicine ball throw (SMBT) [63] and the Y-balance test for the upper extremity [66] have been described for evaluation of the front chest throwing performance and static weight bearing shoulder stability, respectively. However, normative data and cut-off values for injury prevention and return to play are lacking.

Conclusions

This paper describes science-based guidelines for the rehabilitation of the overhead athlete with glenohumeral instability. Besides focusing on rotator cuff strength, ROM and scapular performance, the functional kinetic chain should be implemented throughout all stages of the rehabilitation program. Return to play should be based on subjective assessment as well as objective measurements of ROM, strength, and function.

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