INTERNAL IMPINGEMENT IN THE TENNIS PLAYER: REHABILITATION GUIDELINES

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ABSTRACT
Internal impingement is a commonly described cause of shoulder pain in the overhead athlete, particularly the tennis player. Three shoulder dysfunctions, frequently correlated with internal impingement symptoms, need our attention in the rehabilitation strategy of internal impingement in the tennis player: 1/ acquired glenohumeral anterior instability, 2/ loss of internal rotation ROM, and 3/ lack of retraction strength.

Based on recent literature, the following guidelines are proposed in the rehabilitation of the tennis player with internal impingement symptoms: 1/ shoulder rehabilitation should be integrated into kinetic chain training, not only in the advanced phases of the athlete’s rehabilitation, but from the initial phases, 2/ angular as well as translational mobilizations can be used in the treatment of acquired loss of glenohumeral internal rotation range of motion to stretch the posterior structures of the glenohumeral joint, and 3/ in the rehabilitation of scapular dyskinesia, the therapist should focus on restoration of intramuscular trapezius muscle balance in the scapular exercises, with special attention to strength training of the retractors.
INTRODUCTION:
Chronic shoulder pain is probably the most common upper extremity problem in recreational and competitive overhead athletes \(^1,37,48\). Throwing athletes, athletes involved in racquet sports such as tennis, volleyball players and swimmers need full, unrestricted upper extremity function to optimally perform in their sport\(^40\).

Non-traumatic shoulder pain in the overhead athlete is a diagnostic challenge. The causes of chronic shoulder pain are numerous, but often difficult to identify and diagnose\(^4,9,41,45,57\). Research indicates that shoulder impingement is the most common cause of shoulder pain in overhead athletes\(^2,52\). In recent literature, impingement has been described as a group of symptoms rather than a specific diagnosis. In this current opinion, it is thought that numerous underlying pathologies may cause impingement symptoms. Glenohumeral instability\(^25,28,31,40\), rotator cuff or biceps pathology\(^25,43\), scapular dyskinesis\(^8,28,30\), and glenohumeral internal rotation deficit\(^7,42,56\) have been associated with impingement symptoms in clinical literature. Different anatomical structures can be impinged internally or externally, probably depending on the motion and loading put on the shoulder during the pain-provoking activity\(^9,50\). However, a possible instability in the shoulder is often “silent” and difficult to demonstrate by ordinary tests and has therefore by some been termed “functional instability”. It is now thought that functional instability in the shoulder may lead to a vicious circle involving microtrauma and secondary impingement, and may eventually lead to chronic shoulder pain\(^50\).

Since the first paper, published by Walch\(^55\) et al., describing a new site of impingement between the humeral head and the postero-superior rim of the glenoid, internal impingement has been suggested to be a common cause of chronic shoulder disorder in overhead athletes\(^5,21,26\). This kind of impingement occurs in the cocking position of throwing, with the glenohumeral joint in maximal external rotation, maximal horizontal abduction, and, depending on the sport, in abduction or forward flexion. Walch\(^55\) et al. demonstrated performing shoulder arthroscopy with the shoulder placed in 90° of abduction and 90° of external rotation (90/90 position) that the supraspinatus and infraspinatus tendons tend to rotate posteriorly. This more posterior orientation of the tendons aligns them such that they become compressed between the humeral head and the postero-superior rim of the glenoid. In general, overhead athletes with internal impingement have posterior shoulder pain, tenderness of the infraspinatus tendon on palpation, and are typically athletes intensively active in overhead sports such as tennis\(^20\). Internal impingement particularly occurs when the humeral shaft goes beyond the plane of the body of the scapula during the cocking position of throwing. Under normal circumstances, the scapula goes into retraction simultaneously with the horizontal abduction movement of the humerus. When the body of the scapula and the humeral shaft fail to remain in the same plane of movement during the cocking phase of throwing, encroachment of the rotator cuff tendons between the humeral head and the glenoid rim may cause internal impingement symptoms. This phenomenon is called “hyperangulation”\(^7\). However, in spite of the documented structural pathology and cuff lesions, demonstrated to be related to internal impingement symptoms by a number of authors\(^7,25,55\), very often functional disturbances, such as subtle glenohumeral instability, glenohumeral ROM restrictions and scapular dysfunction and muscle stiffness are suggested to be associated with internal impingement symptoms, rather than structural deficits and pathologies\(^8,11,33,44\). These dysfunctions often are the base for conservative treatment, in particular rehabilitation exercises and need our attention, in the prevention and rehabilitation of shoulder pain in the tennis player.

Numerous studies have been performed, examining the possible causes and biomechanical backgrounds of internal impingement. In general, two pathological mechanisms have been described in the possible etiology of internal impingement: excessive humeral translations,
compromising glenohumeral congruence\textsuperscript{22}, and scapular dyskinesis, decreasing the quality of functional scapular stability, and hence jeopardizing overhead shoulder function\textsuperscript{44}. The most commonly described cause of excessive humeral translations is anterior shoulder instability\textsuperscript{57}. Overhead athletes very often exhibit acquired glenohumeral instability, characterized by laxity of the anterior capsule, as a result of the extreme use of their shoulder during overhead throwing or smashing activities. This kind of acquired instability is often referred to as A.I.O.S. (Acquired Instability Overuse Syndrome)\textsuperscript{57}. Several authors suggest this kind of instability in recreational and professional tennis players\textsuperscript{36,52,57}.

A second mechanism related to increased humeral translations is tightness of the posterior structures\textsuperscript{6,7,44,57}. A consistent finding present during the examination of the overhead athlete is reduced dominant arm internal rotation ROM\textsuperscript{7,40,44,56}. Several possible mechanisms have been described to explain the Glenohumeral Internal Rotation Deficit (G.I.R.D.)\textsuperscript{3,34}. The tightness of the posterior capsule as well as the muscle tendon unit of the posterior rotator cuff has been believed to limit internal rotation joint rotation. Burkhart\textsuperscript{7} et al. defined G.I.R.D. as a loss of internal rotation of 20 degrees or more compared with the contralateral side. When the posterior structures of the glenohumeral joint are shortened, this may compromise the hammock- function of the inferior glenohumeral ligament (IGHL), and increase the risk for impingement symptoms during throwing. Under normal circumstances, the IGHL functions as a hammock in the stability of the glenohumeral joint. However, in case of tightness of the posterior band of the IGHL, the humeral head will translate anteriorly, as a result of imbalances between the anterior and posterior band of the IGHL. There is some discussion about the humeral head movement during the cocking position of throwing or overhead serving in tennis. According to some authors, the posterior band of the IGHL moves inferiorly and a slightly anteriorly of the humeral head, thus inducing a postero-superior translation of the humeral head. This mechanism possibly explains the findings of internal impingement symptoms in the cocking position\textsuperscript{7}. During the follow-through phase of throwing, the posterior band of the IGHL is at the postero-inferior side of the humeral head. In case of tightness of this part of the capsule, it will induce antero-superior translations of the humeral head, thus increasing the risk for subacromial impingement. However, other studies\textsuperscript{24} suggest an anterior and inferior translation of the humeral head during cocking with a tight posterior capsule. As a result, posterior capsule shortness possible increases internal as well as subacromial impingement in the overhead athlete\textsuperscript{6,7,24}. Loss of internal rotation ROM in tennis players has been demonstrated by a number of authors\textsuperscript{17,18,29}.

Besides the glenohumeral component as a possible cause of internal impingement, scapular dyskinesis may play an important role in functional shoulder pain in the overhead athlete\textsuperscript{8,33}. The role of the scapula in normal athletic shoulder function and in shoulder pain in the overhead athlete has been extensively described in literature\textsuperscript{14,30}. Clinical experience as well as scientific data shows that athletes with shoulder pathology consistently demonstrate abnormalities in scapular rotator activity\textsuperscript{11,12,13,15,40,48,54}. Numerous studies have been published examining muscle activity in the scapular muscles during a variety of movements in athletes involved in overhead activities. Most authors suggest, based on their data, alterations in muscle activity in upper trapezius, lower trapezius and serratus anterior in patients with symptoms of impingement\textsuperscript{11,12,13,15,49,54}.

During overhead throwing, it is imperative that the scapula can move towards retraction as well as protraction. In the cocking phase, sufficient retraction is necessary to avoid hyperangulation and impingement symptoms\textsuperscript{30}. A number of studies have shown that overhead athletes have a scapular muscle balance protractors/retractors slightly smaller than 1, meaning protractors are stronger than retractors\textsuperscript{16,13,57}. Normal non-athletic subjects have equal strength in their
protractors and retractor\textsuperscript{10}. This shift in scapular muscle balance may be the result of sport specific adaptations, however a lack of retraction strength may increase the risk for hyperangulation, and hence internal impingement.

In summary, three diagnoses, correlated with internal impingement symptoms, need our attention in the rehabilitation strategy of internal impingement in the tennis player: 1/ acquired glenohumeral anterior instability, 2/ loss of internal rotation ROM, and 3/ lack of retraction strength. These diagnoses are functional disorders rather than structural pathologies and probably are interrelated to each other. Although it is not clear which is the cause-consequence relationship between these items, they deserve our attention in the prevention and rehabilitation of shoulder pain in the tennis player.
REHABILITATION OF ACQUIRED INSTABILITY

The following description of rehabilitation guidelines for shoulder instability in the overhead athlete is based on clinical literature rather than scientific rationale. The reader however should take into account that although there are numerous authors, describing a rehabilitation protocol for shoulder pathology in the overhead athlete, scientific evidence to support the effect of these rehabilitation protocol is scarce. Future investigations should focus on examining the efficacy of these exercise protocols.

The rehabilitation process for overhead athletes with acquired instability must restore muscular balance, muscular endurance as well as gradually restore proprioception, dynamic stability, and neuromuscular control. In the initial phase the major treatment goals are restoration of rotator cuff muscle balance, baseline proprioception and local muscle control.

In view of the observation that very often ER/IR ratio is decreased in overhead athletes, special attention goes to restoration of muscle control and muscle strength of the external rotators. Closed kinetic exercises are also performed in this phase (figure 1). Axial compression exercises stress the joint in a weight bearing position, resulting in joint approximation, and improving co-contraction of the rotator cuff muscles.

The treatment goals during the intermediate phase are improving functional dynamic stability under circumstances of increasing complexity and specificity, introducing eccentric exercises and open kinetic chain exercises in preparation of a throwing program, and enhancing muscle strength of all glenohumeral muscles.

The third phase of a functional rehabilitation program, the advanced phase, is designed to prepare the athlete to full return to athletic activity. Strengthening exercises are continued, and plyometric drills are introduced. Plyometric exercises consist of quick powerful movements, activating the stretch-shortening cycle of the muscle. Initially the athlete performs the plyometrics using both hands and with their shoulder in a moderate external position (figure 2). Two-hand drills are progressed to one-hand drills, with increasing velocity and resistance (figure 3).

In recent literature, the role of the kinetic chain has been emphasized in the rehabilitation of the tennis player with shoulder pain. The rationale behind the kinetic chain principle is that other body parts, such as the lower extremities or the trunk, should be integrated in the shoulder rehabilitation program, in order to prepare the whole body of the athlete to return to athletic activity, and not only his shoulder. Core stability, lower extremity balance, and diagonal movement patterns are examples of facilitation of the kinetic chain into the rehabilitation of the shoulder, and are illustrated in the figures 4 to 8. In recent rehabilitation programs, kinetic chain exercises are not only prescribed in the sport specific phase of the rehabilitation process, but from the initial phase.

REHABILITATION OF G.I.R.D.

In general, two kinds of stretching exercises are described in literature to reduce G.I.R.D. Angular stretches as well as translational mobilizations are used to increase glenohumeral internal rotation ROM.

In the angular stretching techniques, internal rotation or horizontal adduction movements are passively performed, by the therapist, or by the patient. A popular stretch is the “sleeper’s
stretch” (figure 9 and 11). The patient’s shoulder is lying on his injured side with the shoulder in 90° forward flexion. While the scapula is manually fixed into retraction, glenohumeral internal rotation is performed passively, thus stretching the posterior structures of the shoulder. Attention should go to the patient’s reaction: a stretching feeling at the back of the shoulder is allowed, however if the patient feels pain anteriorly, the intensity of the stretching should be reduced by limiting the amount of forward flexion, or turning the trunk slightly backwards, thus decreasing the strain on the posterior structures.

In the “cross body-stretch”, the arm is moved into horizontal adduction (figures 10 and 12). Recently, Mc Clure at al. demonstrated significant better results of this stretching technique with respect to increase of internal rotation range of motion compared to the sleeper’s stretch in subjects with restricted internal rotation ROM. However, further research is needed on larger patient populations to confirm these results and to correlate the findings to other clinical entities such as pain and symptoms in these patients.

In addition to the angular stretching techniques, translational mobilization techniques have been described to increase internal rotation ROM. In order to influence the posterior ligaments, high grade end range dorsal glide mobilizations can be performed. The patient’s shoulder is placed in endrange of internal rotation (figure 13) or horizontal adduction (figure 14), and the therapist performs manual translational glides in dorsal direction. Research indicates that particularly high grade end range mobilizations result in permanent increase of ROM, more than low grade mid range mobilization techniques. However, it should be noted that these investigations were performed on patients with adhesive capsulitis or in cadaver specimens. Moreover, as mentioned earlier, internal impingement may be associated with subtle glenohumeral instability, and GIRD in the tennis player may be present in a potentially unstable shoulder. Therefore the recommendation of high grade mobilizations should be interpreted with caution, and limited to be used in case of GIRD in the absence of glenohumeral instability.

Little scientific evidence is available regarding the effectiveness of these techniques, and the possible decrease of internal impingement symptoms. Moreover, literature discusses the cause of G.I.R.D. being the result of stiffness of the posterior capsule, the IGHL, muscle or bony abnormalities such as retroversion of the humeral head. Future research should emphasize the possible causes of the loss of internal rotation ROM in overhead athletes, as well as on the efficiency of the physical therapy treatment techniques.

REHABILITATION OF SCAPULAR DYSKINESIS

In view of the new insights and research findings on the role of the scapula in shoulder pathology, current exercise protocols emphasize the importance of scapular muscle training as an essential component of shoulder rehabilitation. Particularly, restoration of muscle control and balanced co-activation is a challenge to the clinician. For patients with an imbalance in the scapular muscles, selective activation of the weaker muscle parts with minimal activity in the hyperactive muscles is an important component in the reduction of the imbalance. Since a lack of activity in the lower trapezius (LT), middle trapezius (MT) and serratus anterior (SA) frequently is combined with excessive use of upper trapezius (UT) the balance ratios UT/LT, UT/MT, and UT/SA are of particular importance. In addition, integration of shoulder girdle exercises into a global functional kinetic chain pattern has become a treatment goal in shoulder rehabilitation, specifically in overhead athletes.

The selection of appropriate exercises in the rehabilitation of scapular muscle performance depends upon the actual strength of the muscles, but also upon the relative strength of one muscle in relation to another. In a study by Ludewig et al., a selection of exercises was introduced with
a low upper trapezius/serratus anterior ratio, meaning high activity in serratus anterior with simultaneous minimal activation of the upper trapezius. However, only UT/SA ratios were examined, and only variations of the push up exercise were performed.

In a recent investigation\(^{16}\), we identified scapular muscle strengthening exercises in which the lower trapezius and middle trapezius were optimally activated with minimal participation of the upper trapezius. Upper, middle and lower trapezius activity was analyzed during twelve commonly used scapular exercises with surface electromyography and UT/LT and UT/MT muscle balance ratios were calculated. Four exercises were selected as exercises with a low UT/LT or MT/LT ratio (figure 15): sidelying forward flexion (A), side-lying external rotation (B), prone horizontal abduction with external rotation (C), and prone extension in neutral position (D). Since a number of studies show that overhead athletes with impingement symptoms show decreased activity in the lower as well as in the middle trapezius with excessive activation of the upper part\(^{11,12,13,15}\), these exercises may be used for restoration of both muscle imbalances.

From a clinical point of view, the major limitation of these exercises can be found in the outcome itself. Indeed, all the exercises selected based on a low UT/LT or UT/MT ratio are performed in a lying position, prone or side lying. However, recent literature emphasizes the importance of functional exercises, resembling daily or sport specific arm function, and integration of the shoulder rehabilitation into a functional kinetic chain\(^{8,30,38}\). These treatment goals are very difficult to accomplish with the patient lying prone or on his side. Diagonal patterns, combined with trunk and lower limb stabilization, as promoted by a number of authors, are not possible in these exercise modalities. Therefore, we propose our exercises to be performed in the early stages of rehabilitation, and prior to more functional kinetic chain exercises, in which functional recruitment patterns can be trained with normalized inter- and intramuscular balance ratios.

CONCLUSION

Internal impingement possibly is the result of acquired anterior instability, acquired loss of internal rotation range of motion due to posterior shoulder stiffness, and scapular dyskinesis. Prior to the rehabilitation program, a thorough physical examination should be performed to define the specific dysfunctions and determine the treatment goals. Physical therapy of acquired instability should focus on integration of the functional kinetic chain in the rehabilitation exercises. Angular stretches and dorsal glide mobilizations may be performed to improve internal rotation ROM, however the therapist should be cautious in case of instability. In case of scapular dyskinesis, restoration of inter- and intramuscular muscle balance are the major treatment goals.
Figure 1: closed kinetic chain exercises in the initial stage of shoulder instability rehabilitation
Figure 2: Initial plyometric exercise: two-hands drill with limited abduction-external rotation of the injured shoulder
Figure 3: Advanced plyometric exercise: one-hand drill with increased abduction-external rotation of the injured shoulder
Figure 4: Kinetic chain integration in closed chain exercises: extending a leg challenges core stability, extension recruitment of the lower limb, and unilateral balance on the other leg
Figure 5: Kinetic chain integration in commonly used shoulder exercises: shoulder extension combined with squatting
Figure 6: Kinetic chain integration in shoulder diagonals: unilateral balance during external shoulder rotation diagonal
Figure 7: Kinetic chain integration in shoulder diagonals: core stability during internal rotation diagonal
Figure 8: Kinetic chain integration during early plyometric exercises: core stability during shoulder plyometrics
Figure 9: “Sleeper’s stretch”: angular stretching into internal rotation, performed by the therapist
Figure 10: “Cross-body stretch”: angular stretching into horizontal adduction, performed by the therapist
Figure 11: “Sleeper’s stretch”: angular stretching into internal rotation, performed by the patient
Figure 12: “Cross-body stretch”: angular stretching into horizontal adduction, performed by the patient
Figure 13: End-range dorsal glide mobilizations (internal rotation)
Figure 14: End-range dorsal glide mobilizations (horizontal adduction)
Figure 15: Scapular exercises for restoration of intramuscular trapezius balance
REFERENCES


