EVALUATION OF MUSCULAR IMBALANCES OF THE SHOULDER IN OVERHEAD SPORTS

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The functional impingement syndrome of the shoulder is very often a result of muscular imbalances at the shoulder girdle. Combined with reduced muscular strength a scapular winging of the medial border of the scapula occurs during eccentric arm movement. The purpose of the study was to evaluate a functional shoulder test to quantify the winging (scapula alata) and muscular deficits. Thirty top-ranked male tennis players of the ATP-Tour participated at the Eurocard Open 1998 in Stuttgart. They performed isokinetic strength test of external and internal rotation and an elevation of the arm with different weights. An additional clinical and in some cases sonographic evaluation was performed.

KEY WORDS: Impingement syndrome, scapula alata, muscular imbalance.

INTRODUCTION: The purpose of the study was to evaluate a functional shoulder test to quantify the clinical diagnosis of scapula alata and muscular deficits. The shoulder represents a complex system of muscular, bony, capsuloligamentous, and cartilagenous components. The shoulder joint is composed of five articulations - sternoclavicular, acromioclavicular, glenohumeral, scapulothoracic, and subacromial - that allow smoothly coordinated motion patterns. Mobility of the shoulder in overhead sports enables athletic performance but also leaves the shoulder vulnerable to injury.

Serving in tennis basically consists of the same motion patterns as, for example, baseball pitching. This has been well described by Jobe (1996). In the cocking phase of throwing or serving in tennis very high angular velocities and internal torque have been suggested to occur at the humerus. To compensate this, a perfectly coordinated activity of all the scapular muscles is required, for stabilising the humeral rotation (Figure 1).

Highly eccentric activity of the m. infraspinatus and m. teres minor is needed to decelerate the speed and to stabilise the center of rotation of the glenohumeral joint in the follow-through phase of throwing.

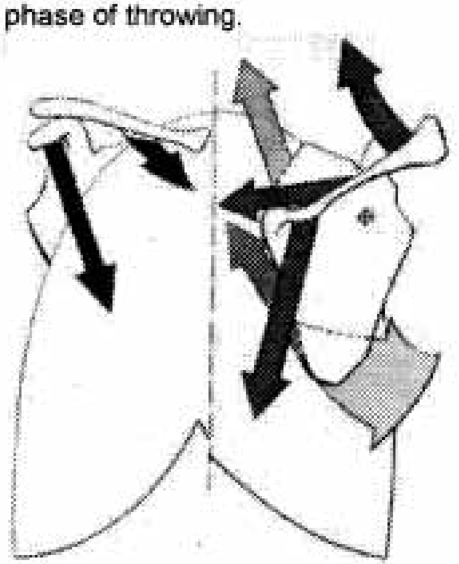

Figure 1 - The major scapular stabilisers m. serratus anterior, m. levator scapulae, m. trapezius and m. rhomboideus. (adapted from: Kapandij 1992)

Chronic shoulder pain in overhead athletes is often caused by a failure of the kinematic chain. Various factors, such as imbalance of the scapulothoracic muscles, m. infraspinatus insufficiency and stiffness of the dorsal capsule can be responsible for this. In addition, the morphology of the thoracic spine has to be taken into consideration in analysing functional problems.

Various authors described abnormalities of scapulothoracic motion. Warner (1992) used dy-

namic and static 'Moire' topographic testing and found a highly increased rate of scapulothoracic dysfunction in patients with impingement syndrome. Kibler (1995) demonstrated scapulothoracic asymmetry and a greater lateral scapular slide documented by direct x-ray measurements.
In addition to the findings of Warner (1992) and Kibler (1998) it has been our clinical experience that imbalance of scapulothoracic muscles may cause an increased scapular winging. Scapular winging describes a prominent lift off of the medial border of the scapula in relation to the thoracic wall (scapula alata). It can be seen during eccentric lowering of the arm against minor resistance (Figure 2). The kinematic muscle chain is disturbed by a relatively high muscle tone of the m. levator scapulae and m. pectoralis minor as well as a relative weakness of the m. rhomboid and m. serratus anterior. During concentric elevation in the scapula plane usually no scapular winging occurs. Severe scapula winging is most commonly related to neurologic injury or neuromuscular diseases. This clinical entity of scapular winging plays an important role in detecting pathologic motor pattern.

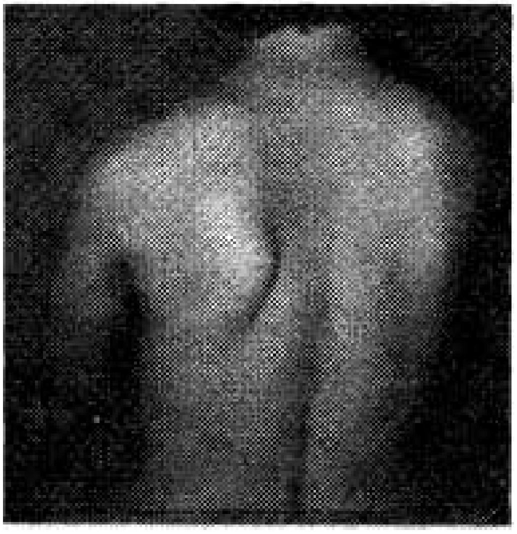

Figure 2 - Eccentric lowering of the arm against slight resistance: moderate scapular winging is demonstrated

METHODS: Isokinetic Strength: The dominant and non-dominant shoulder were measured for all subjects in three maximum intemal and external concentric contractions with an isokinetic machine (MOFLEX) . The volunteer was placed in a standardised sitting position, The elbow was flexed to 90 degrees and the arm was slightly abducted. The starting point for the intemal rotation was set at 30° external rotation and for the external measurement at 30" internal rotation. The maximum value of all three contractions was stored for further analysis.
Kinematic Analysis: The amount of scapular winging during concentric and eccentric elevation was analysed by an automatic tracking video system (ELITE, BTS Mailand). The volunteer was seated with the chest fixed at a bench. The outstretched arm was pronated and elevated 90" in the plane of scapula. Two different weights (0.1 kg and 3.7 kg) were applied. Infrared reflecting markers were fixed on the inferior border of the scapula and the thoracic spine (Th10). Specially designed software, was used to calculate the differences in anterior/posterior direction of the markers on the spine and on the scapula. The differences represent linear movement of the marker in mm in the sagittal plane. In order to define starting and end point of the movement one marker was positioned on the handgrip of the weights. Besides this, clinical testing, ROM and in some cases sonography were realized.

RESULTS : ROM: Clinical examination of the professional tennis players showed an internal rotation deficiency of more than 20" at the dominant side compared to the non-dominant side (Figure 3).
Isokinetic Strength: Mean values of the isokinetic testing indicate a ratio from 40 to 60 %. These findings were similar for both sides and represent a normal range.

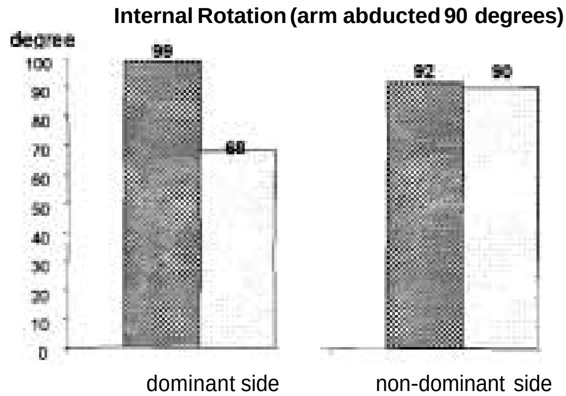

Figure 3 - Mean range of motion of the tennis players show a internal rotational deficiency at the dominant side together with an increased flexibility for external rotation. The values were clinically evaluated.

Also the absolute values did not show any specific differences (Figure 4). Looking at the individual results, three out of the 30 players achieved a ratio less than 30% for external rotational strength on the dominant side (Figure 4). The ratio was calculated as percent from the total internal and external forces. These reduced values were associated with the clinical finding of severe infraspinatus atrophy in each of these cases.

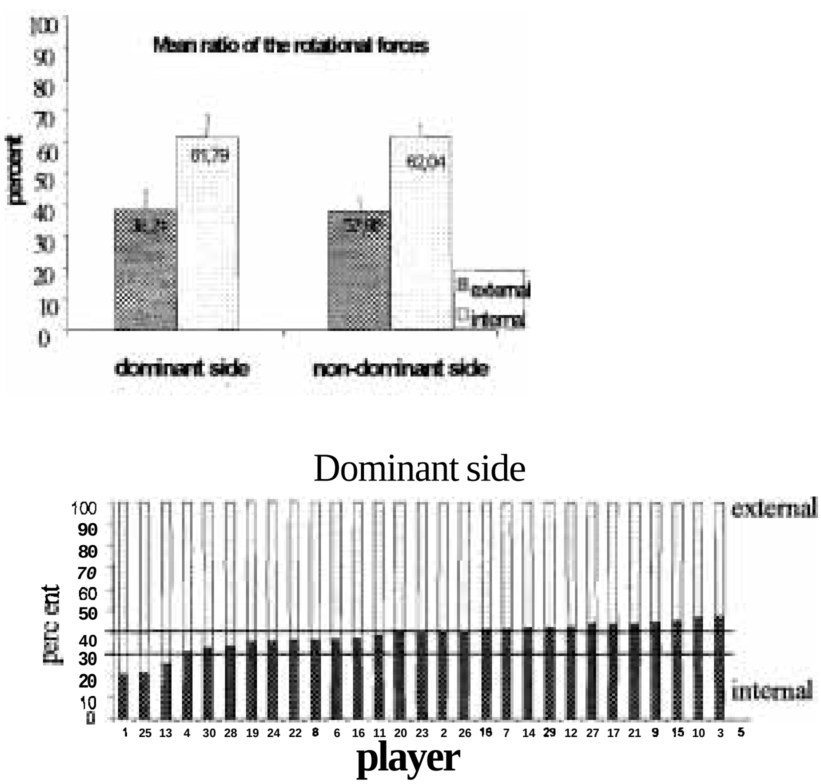

Figure 4 - On top mean forces and stdv. for external and internal rotation of the dominant and **non-**dominant side. Lower diagram shows the externallinternal values for each player only for the dominant side.

Scapula Winging: In some players an increased scapular winging was visible. In Figure 5 a typical movement cycle of scapula winging during arm elevation and lowering is shown. The individual graph of this player shows a difference of 40 mm between spine and scapula which is increased up to 50 mm even before the weight is lifted. During the concentric abduction the difference decreased to less than 20 mm. In the eccentric adduction phase the difference is increased and in the following stop phase, where the weight must be held, again a value of 50 mm is achieved.

DISCUSSION: The tennis players show a marked difference in the ROM between the dominant and non-dominant side. This is interpreted as a functional adaptation to the specific demands especially for the serve in tennis, where a good external rotation is necessary for the cocking movement. Three players show a reduced internal strength. This lack of internal rotational ability

has been previously described as a function of duration of competitive overhead work (Eggert and Holtzgraefe 1993). The reason is probably a dorsal capsular stiffness as a result of chronic microtrauma of the capsular-tendinous structures. Infraspinatus weakness has been described in detail in overhead activities (Eggert and Holtzgraefe 1993, Rorich and Kollmansberger, 1995). Weakness of the m. infraspinatus causes anterior-superior migration of the humeral head resulting in dysfunctional ball-and-socket kinematics. The etiology of m. infraspinatus atrophy is still unknown. Some authors favour a chronic nerve injury caused by tension or compression neuropathy of the suprascapular nerve. Chronic microtrauma of the muscle and tendon itself is also currently being discussed. A secondary neuromuscular inhibition of infraspinatus activity should also been taken into consideration. Due to permanent lateralisation and deficient stabilisation of the scapula origin and insertion of the m. infraspinatus muscle are elongated and muscular weakness may occur. The question under consideration is whether the observed infraspinatus weakness in overhead athletes is caused by a primary pathology or whether it is a secondary phenomenon. Registration of the scapula movement especially a three dimensional analysis is very difficult by video diagnoses. Because of bone-to-skin displacements, the trajectory of an external marker may differ from the movement of the scapula (van der Helm 1998). In our case only the sagittal movement of one marker is interpreted and for the analyses the start and end points are of importance. With this method it is possible to evaluate scapula winging.
The subjects with the lowest external force have a higher difference between spine and scapula that can reach values of more than 40 mm. This result may support the assumption that a weak m. infraspinatus results in an increased winging of the scapula. Whether these differences are pathologic or a sign of functional adaptation needs further investigation. To evaluate a valid test these results should be improved with EMG records to see how the activation characteristic is changing when the fixation of the scapula at the thorax is weak.

REFERENCES:

Eggert S, Holtzgraefe M. (1993) Compression neuropathy of the suprascapular nerve in high-performance volleyball players. In: *Sportverletzung* Sportschaden Sep.7(3), 136-142.
Jobe F.W. (1996) Operative techniques in Upper extremity sports injuries. In: Mosby-Year Book.
Kapandij, I.A. (1992). Funktionelle Anatomie der Gelenke. Bd. 1. Obere Extremitat. Ferdinand-Enke Verlag Stuttgart.
Kibler, WB. (1995). Current concepts of shoulder biomechanics for tennis. In: Tennis - Sports medicine and science. Second international conference of sports medicine and science in tennis. May 19 - 21. 1994 Essen, Germany. Hrsg. Krahl , H.; Pieper, H.-G., Kiebler, W.B., Renstrom, P.A.: by Walter Rau Verlag, Düsseldorf.
Kibler, WB. (1998). The role of the scapula in athletic shoulder function. *Am.* J. Sports Med. 26, No. 2 325-337.
Rorich F, Kollmannsberger A. (1995). Atypisches Engpaßsyndrom des n. suprascapularis distal der incisura scapulae. In: *Nervenarzt*, 66,638-642
Van der Helm, FCT.(1998) A standardized protocol for motion recordings of the shoulder. In: Homepage international shoulder group of ISB.
http//www.fbw.vu.nl/reserach/Lijn_A4/shoulder/isg/proposal/protocol.html.
Warner, JJP, Micheli, LJ, Arslenian, L et al. (1992) Scapulothoracic motion in normal shoulders and shoulders with glenohumeral instabilty and impingement syndrom. A study using Moire Topographic analysis. Clin. Orthop. 285, 191-99.

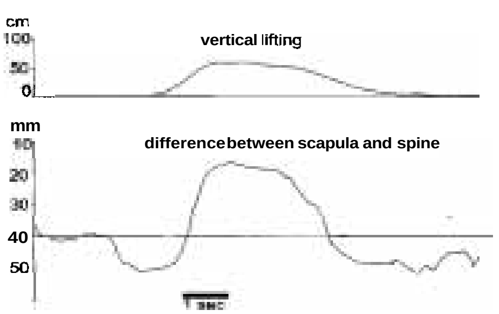

Figure 5 **- Movement trajectory of one individual player during one lifting cycle. The vertical lifting of the arm (upper curve) is expressed in cm over the time of about** 6 **seconds. The distance between thoracic spine and scapula is scaled in mm (lower curve). The x-axis in the lower graph represents the starting point of the movement which was at a distance of 40 mm.**