Thoracic spine function: assessment and self-management

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OVERVIEW

Thoracic spine function is vital in preserving health to the glenohumeral joint, reducing the risk for shoulder joint pathology. Ideal alignment of the thorax not only supports efficient kinematics of the scapulothoracic joint, but also supports the force development of key stabilising muscles that influence the shoulder complex. This article will present evidence about the thorax and its influence on shoulder performance, as well as providing methods to screen and self-manage the thoracic spine in order to optimise function at the shoulder girdle.

Introduction

A common mechanism for injury at the glenohumeral joint is impingement syndrome,[42] whereby repetitive motions and altered mechanics may result in pathophysiological changes within the rotator cuff tendons, superior labrum, subacromial bursa and/or the long head of the biceps brachii.[7] Shoulder impingement syndrome may be categorised as either external or internal impingements, depending on the mechanism.[29] External shoulder impingement refers to pathology of the soft tissue residing within the subacromial space, secondary to recurring compression between the humeral head and coracoacromial arch.[46] This mechanism tends to occur between 45-60° of shoulder elevation, where the greater tubercle is within close proximity to the coracoacromial arch.[36] Beyond this point, the insertion site for the rotator cuff muscles moves posteriorly away from the acromion of the scapula as the humerus externally rotates relative to the glenoid fossa.[2]

More commonly associated with throwing sports,[38] internal shoulder impingements describes the entrapment of the deep surface of the supraspinatus and infraspinatus tendons, between the head of the humerus and the posterior-superior aspect of the glenoid labrum.[23] This mechanism mainly occurs when the glenohumeral joint is orientated in an abducted and external rotated position,[23] as seen in the late cocking phase in the throwing motion.

A range of extrinsic risk factors have been indicated as increasing the likelihood of developing both types of shoulder impingements.[48] Both local[20,21] and global[6,28] movement faults during tasks that require shoulder elevation have also been implicated in impingement syndromes. Abnormal scapular kinematics during shoulder elevation tasks have been linked with glenohumeral joint pathologies related to impingement, such as reduced scapulothoracic upwards rotation[20,33,34] and posterior tilt.[20,37] These dysfunctions are impacted by soft tissue

'adequate thoracic extension must be present in order to enhance scapula kinematics during shoulder elevation tasks'

extensibility of the scapulohumeral[3] and thoracoscapular[4] muscles, as well as by altered activation patterns within the scapulothoracic upward rotator muscles.[8-11,51]

An important factor influencing scapula kinematics as it relates to shoulder function is the thoracic spine.[16,17] Limited motion at the thoracic spine has been shown in patients with shoulder impingement syndrome,[41,49] and is associated with decreased range of motion and significant reductions in force output during shoulder abduction.[28] As the scapula's position in space in determined by the orientation of the rib cage and many of the muscles that attach to the scapula originate from the spine,[45] the thorax possesses a tremendous influence over scapulohumeral function. As such, it is the objective of this article to establish the mechanical contribution the thoracic spine provides in maintaining upper extremity function, along with strategies to measure and improve thoracic spine mobility.

Thoracic spine contribution to shoulder function

Many sporting activities demand the shoulder complex achieve 180° of shoulder elevation. This requires contributions from multiple joint segments including the glenohumeral, acromioclavicular and sternoclavicular joints,[45] as well the thoracic spine.[19] With 120° of elevation being contributed by the glenohumeral joint, the remaining 60° is supplied by the scapulothoracic joint (a physiological joint representing motion from the acromioclavicular and sternoclavicular joints[44]) through upwards rotation.[45] These primary joint movements are complemented by secondary motions. At the glenohumeral joint, shoulder elevation occurs with concomitant external rotation,[30,35,55] allowing the greater tubercle to travel beneath the coracoacromial arch, increasing the acromiohumeral interval.[5] Upwards rotation at the scapulothoracic joint is accompanied by up to 30° of scapula posterior tilt,[39] further reducing the compression imposed on the subacromial tissue.[34]

In the sagittal plane, thoracic extension is synchronised with shoulder elevation,[16,17,50] and contributes to total range of motion during shoulder elevation.[16] Due to the structural composition of the facet joints and rib attachments, extension occurs predominantly in the lower region, with smaller contributions from the upper region of the thorax.[16,19] Specifically, in healthy subjects, 3.7° versus 7° of extension has been measured in the upper and lower thoracic regions respectively during bilateral shoulder elevation. This reflects the total range of motion that occurs during overhead pressing exercises.[40] If an athlete were unable to achieve the required range of motion, neighbouring joint segments may have to compensate in order to orientate the hand above the head, increasing compression on the lumbar facet joints (in the case of a lumbar extension compensation), or the subacromial tissues (in the case of a glenohumeral flexion/abduction compensation).

Low extension capacity in the thoracic spine, particularly in the upper region, is also crucial for supporting optimal scapula kinematics. Although thoracic extension occurs in both the upper and lower regions, upper thoracic extension is phase-locked to upward rotation of the scapulothoracic joint.[17] Extension of the thoracic spine also supports posterior rotation of the scapula during shoulder elevation,[28] as the scapula follows the contour of the thorax. This motion is critical, as it elevates the anterior aspect of acromion away from the head of humerus, increasing clearance for the subacromial tissue.[34] As posterior tilt is also linked to recruitment of key scapulothoracic stabilisers such as the serratus anterior and the lower trapezius,[36] thoracic mobility also facilitates recruitment of these muscles.[54] Therefore, adequate thoracic extension must be present in order to enhance scapula kinematics during shoulder elevation tasks, potentially reducing the risk of developing external impingement syndrome.

Due to the alignment of the facet joints, a large capacity for rotation is possible at the thoracic spine when compared to the lumbar segments. However, rotation is markedly reduced when the spine is in a flexed position due to the approximation of joint surfaces and tension created within the ligamentous structures.[18] Thus, athletes who display limitations in both thoracic extension and rotation are advised to focus initially on improving extension capabilities before addressing rotational capacity.

Athletic-based movements such as throwing require a significant amount of rotation[1,56] and extension[43] at the thoracic spine in order to enhance efficiency of the throw, and reduce glenohumeral joint torques. In instances where the throwing athlete does not produce adequate thoracic rotation, compensatory movement strategies may be necessary. At the glenohumeral joint, a lack

of thoracic rotation may lead to increases in horizontal abduction and external rotation in order to achieve ball displacement, increasing the risk for developing internal shoulder impingement.[23] During throwing movements, rotation at the thoracic spine also has the potential to decelerate the upper extremity following ball release. A lack of thoracic rotation may lead to increased stress being consigned to the posterior scapulohumeral musculature in order to decelerate glenohumeral horizontal adduction.

Assessing thoracic motion

Although isolated measures of thoracic spine mobility have their place within the screening process, assessments which integrate movement of the upper extremity are likely more appropriate. Where limitations are observed during these tests, breakout screens which isolate the thoracic spine will further aid practitioners to determine if the deficit is due to a mobility restriction or motor pattern dysfunction. For example, when limited thoracic extension is observed during a bilateral shoulder elevation test, practitioners should then consider using the occiput-to-wall test to determine if the athlete possesses the capacity to extend the thoracic spine. Using this process, practitioners will be able to make a clear distinction as to whether the athlete possesses a mobility restriction, or their preferential movement strategy fails to incorporate the available thoracic spine motion.

This approach (see Figure 1) ensures that the appropriate exercise prescription is provided for the athlete, increasing the effectiveness of prescribed interventions.

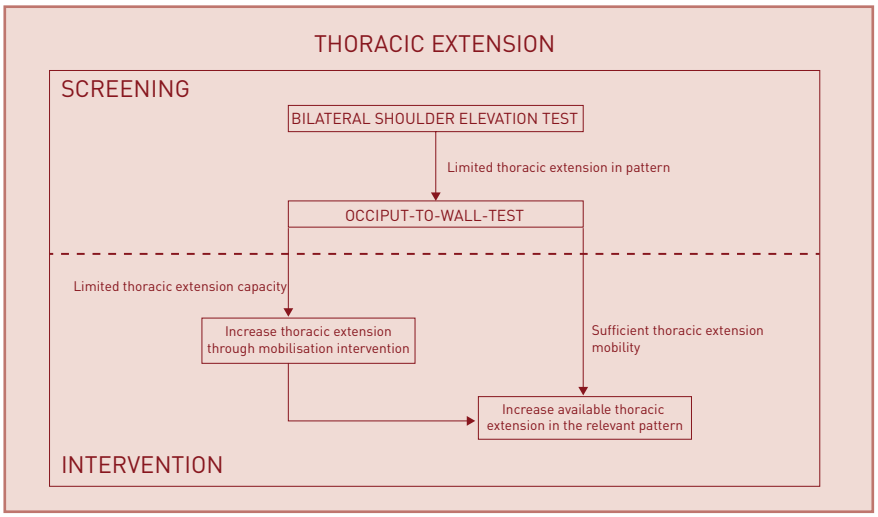
Additionally, assessing movement patterns under load should also be considered, as high load stabilisation strategies are modulated by separate central processes to the low load movement system.[24] This is especially important in the thorax, as athletes using excessive activation of the abdominals as part of a co-contraction strategy used in order to stiffen the spine during a loaded movement, may possess increased spinal flexion (or at least reduced extension range of motion). Therefore, load may be added or velocity increased to the bilateral shoulder elevation test to allow practitioners to assess the athlete's high load stabilisation strategy. This may also be accomplished by utilising more traditional movements such as the overhead press.

In the assessment of thoracic rotation, athletes should first be screened to determine if they possess sufficient thoracic extension (Figure 2). As previously stated, when an athlete presents in a hyperkyphotic thoracic spine, rotational capacity will be limited due to the taut passive structures.[18] Therefore, if an athlete possesses a lack of torso rotation during the seated rotation test, the athlete should be cleared for thoracic extension using the occiput-to-wall test in order to establish thoracic extension capacity. If the athlete were to exhibit a lack of thoracic extension, this should be prioritised over thoracic rotation in order to increase overall thoracic spine mobility. This will improve the effectiveness of the corrective strategies employed by ensuring coaches focus on the athlete's requirements.

Figure 1 and 2 also highlight the intervention process required to improve thoracic spine contribution to movement that supports upper extremity function. This process aims to support coaches in being able to make a clear distinction as to whether a mobility restriction exists, or the athlete preferential

Figure 1. Screening process for thoracic extension as it relates to glenohumeral joint function

Figure 2. Screening process for thoracic rotation as it relates to glenohumeral joint function



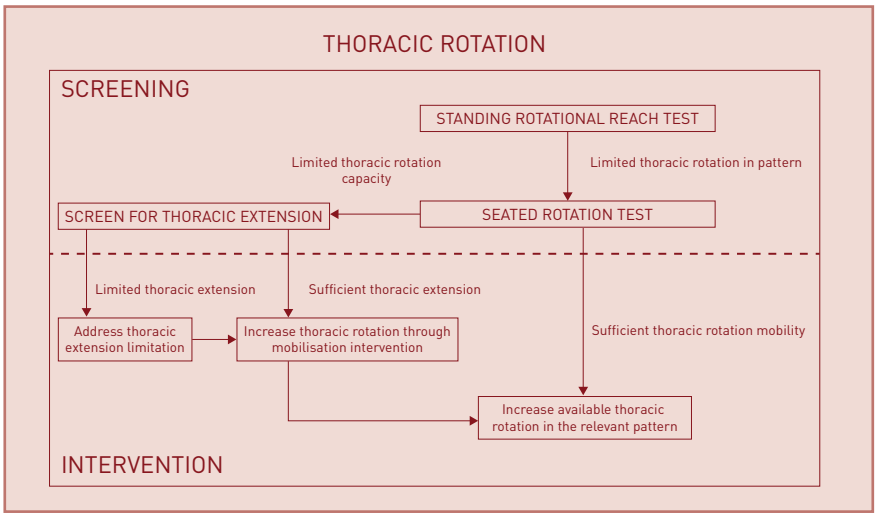


Figure 3.
Bilateral shoulder elevation test. The athlete stands with his feet hip-width apart with the arms in the resting position by their side. The athlete elevates both arms in the scapula plane, keeping the elbows extended and the palmar surfaces of the hands facing the mid line. Load may be added to make comparison between the high and low load strategies

movement strategy does not incorporate the available thoracic spine range of motion. Below are brief descriptions for each screen, along with the relevant information regarding the clinimetric properties of each test where possible. For certain assessments, equipment may be required to achieve objective measures. However, the authors of this paper do not believe that such equipment is essential for identifying restrictions, and coaches can use more subjective means.

BILATERAL SHOULDER ELEVATION TEST

The bilateral shoulder elevation test (Figure 3) allows practitioners to interpret thoracic mobility in the sagittal plane.[14,16,19] In asymptomatic males, 11° of thoracic extension has been shown during bilateral shoulder elevation using photographic image analysis.[19] This technique requires pyramidal markers to be placed at T1, T4, T8 and T12, where the angle between T1-4 and T8-12 can be used to calculate thoracic extension.[19] In this study, Edmondston et al[19] showed a significant correlation (r = 0.79) between measurements of thoracic extension using both photographic and radiograph analysis. However, it is likely that for many strength and conditioning coaches, both techniques are far too time-consuming.

A practically viable alternative involves using two gravity-dependent inclinometers (Figure 4). This technique has reported strong intra-rater reliability (ICC = 0.91 – 0.97),[31] and is performed by placing one inclinometer at the junction between T1 and T2, and another at the junction between T12 and L1.[31] The summation of both angles provides practitioners with a representation of thoracic spine angle at rest.[31] In order to assess thoracic extension during shoulder elevation, the inclinometers can be used to measure thoracic spine position at the end range for bilateral shoulder elevation and compared to the resting position.[15] This point is important to emphasise, as athletes who present with an increased thoracic kyphosis, during a postural assessment, would be expected to achieve greater thoracic spine extension in order to optimise the position of the scapula. Conversely, athletes who display an extended thoracic spine position would demonstrate reduced extension capabilities, with little implication for glenohumeral joint function due to the start position.

OCCIPUT-TO-WALL TEST

Although thoracic extension can be measured in isolation using two inclinometers, the occiput-to-wall test (Figure 5) is a practical alternative that

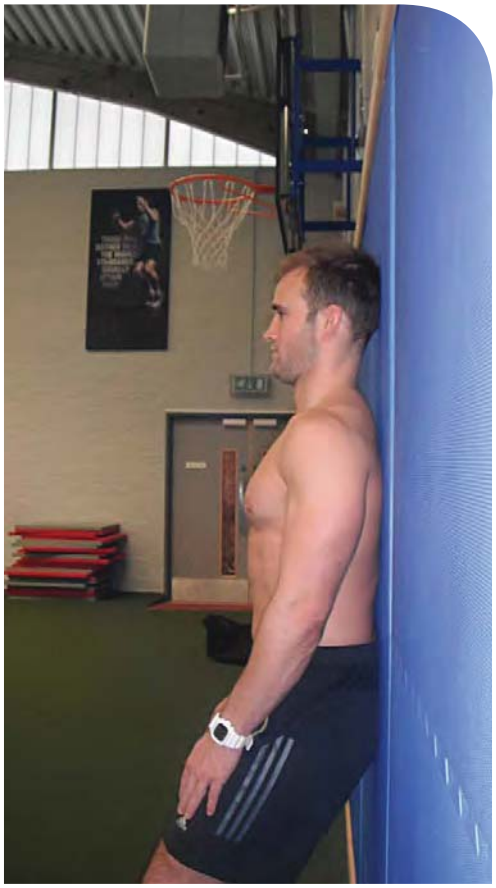


Figure 4. (left)
Measuring thoracic extension using gravity-dependent inclinometer during shoulder elevation as outlined by Crenshaw[15]

Figure 5. (right)
Occiput-to-wall test. The athlete leans with his back against a bare wall, his knees slightly flexed and feet one foot length away from the wall. With the sacrum and upper back in contact with the wall, the athlete posteriorly tilts the pelvis flattening the lumbar spine. From this position, the athlete attempts to make contact between the wall and their occiput, while maintaining a neutral head position

does not require specialised equipment. The purpose of this assessment is to detect restrictions in thoracic extension mobility[47] and has shown strong test re-test reliability (ICC = 0.94–0.96).[22] Although measures of distance can be obtained, strength and conditioning coaches may instead utilise a pass/fail criteria in order to assess if athletes are able to make contact with the wall while maintaining a neutral head position. If this movement outcome is not achieved, it can be interpreted that thoracic extension range of motion is limited. Inability to perform this test is unlikely to be due to myofascial restrictions. In this position, the primary trunk flexors are shortened and with the posterior pelvic tilt required during the test, this would theoretically allow for additional extension of the thoracic spine. To determine if a movement fault was underpinned by myofascial restriction, the test can be manipulated by allowing a slight anterior tilt of the pelvis to limit thoracic extension. In instances where thoracic extension is unchanged with a mild amount of anterior rotation of the pelvis, articular restriction is indicated.

STANDING ROTATIONAL REACH TEST

The standing rotational reach test (Figure 6) allows strength and conditioning coaches the opportunity to understand the integration of thoracic rotation with shoulder horizontal abduction/adduction, rotation at the hips and pronation/supination at the foot complex. Although little evidence is available to support the use of this test or provide normative values, it does have the potential to indicate total body rotational capacity. Also, this test can allow for global restrictions to be qualitatively identified.[13]

When interpreting performance during this assessment, an athlete should be able to rotate their pelvis at least 45° from neutral in the transverse plane.[13] Above the level of the pelvis, the trunk should achieve 90° of rotation, signifying sufficient spinal range of motion. The majority of the rotation occurring at the trunk is achieved through the thoracic spine;[52] the additional 45° represents full range of motion in the thorax. In instances where the pelvis completes 45° of rotation yet the trunk is limited in reaching 90°, hypomobility of the thoracic spine is indicated.

Integrating the upper extremity into this test allows coaches to observe the athlete's preferred movement strategy, as well as any potential compensatory mechanisms around the upper extremity. For example, during an ipsilateral standing rotational reach test, a hypomobile thoracic spine has

Figure 6.
Standing rotational reach test. The athlete stands with feet hip-width apart. In one smooth motion, the athlete rotates as far as possible to one side by reaching with either the ipsilateral or contralateral arm

the potential to cause increased motion at the glenohumeral joint. In this instance, increased shoulder horizontal abduction may occur, with potential repercussions of excessive anterior glide of the humerus relative to the glenoid fossa. This excessive anterior glide secondary to increased horizontal abduction has been suggested as a mechanism for internal impingement syndromes.[12,23] Coaches should also observe compensations which occur outside of the transverse plane as when limited rotational capacity is evident, athletes tend to deviate outside of the desired plane of motion in order to achieve greater range of motion. This is supported by Edmondston et al,[18] who identified excessive lateral flexion in the spine when individuals were limited in thoracic rotation during a seated rotation task.

SEATED ROTATION TEST

The seated rotation test (Figure 7, on next page) is used to measure the degree of thoracic spine rotation.[26,27] Removing contributions from the lower extremities provides a more accurate representation of thoracic spine rotational capacity; however, there is potential for the lumbar spine to compensate and provide additional rotation. This can be prevented by utilising a low box to ensure the hip joint is flexed, forcing the lumbar spine into a position of flexion which limits contributions from the lumbar spine.[26] Strong intra-tester and inter-tester reliability (ICC = 0.85) and an acceptable standard error of measurement (1.72°) have been reported for this test, with normative values of 55°.[27] However, these values are based on non-athletic healthy subjects; caution should be applied when applying standards to athletic populations in different sports.

Self-management techniques

THORACIC MOBILISATION TECHNIQUES

Mobilisation techniques have been shown to increase thoracic range of motion[25] and acutely improve muscle strength in key scapulothoracic stabilisers.[32] In instances where coaches believe thoracic hypomobility to be present, a referral to a medical practitioner is recommended. To complement this, self-mobilisation techniques have been suggested.[27] Although no evidence is available regarding the efficacy of thoracic spine self-mobilisations within healthy populations, Widberg et al[53] demonstrated increased thoracic spine range of motion using self-mobilisations over six weeks in patients with ankylosing spondylitis. It is recommended by the authors of this article that thoracic spine

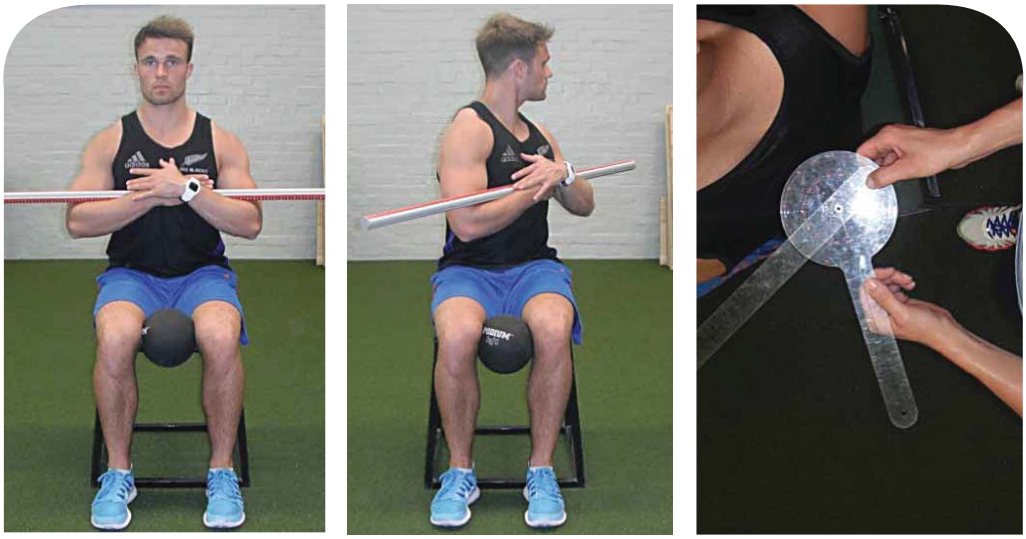


Figure 7. (top three)
Seated rotation test. The athlete is seated in a neutral spine position with both the hips and knees flexed to 90°. A small ball (approximately 21 cm in diameter) is placed between the knees to prevent motion at the pelvis, and a bar is held in front of the body.[27] The athlete is instructed to rotate either side as far as possible. A goniometer can be used to measure spinal rotation (far right). The goniometer is placed at the level of T1-T2 and orientated parallel to the floor. The stationary arm stays in line with the starting position, while the moving arm aligns with the spine of the scapula[26]

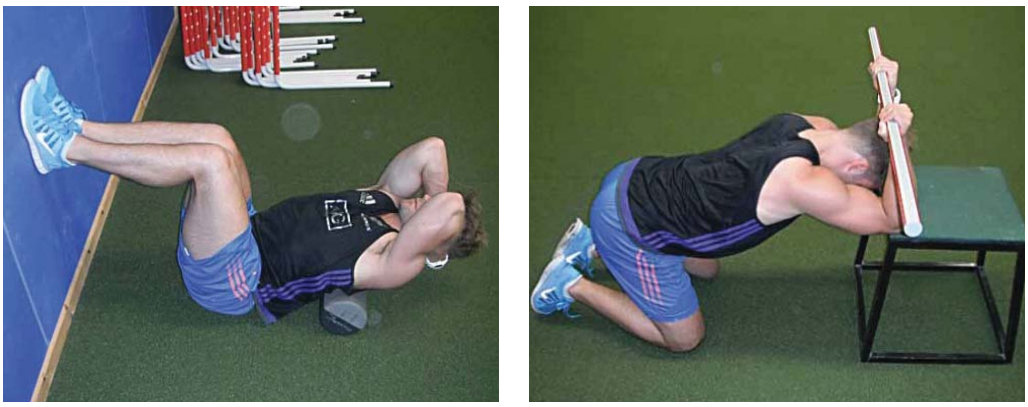


Figure 8. (middle four)
Examples of thoracic mobilisations that aim to prevent compensatory motion of the lumbar spine. Thoracic extension over a foam roller (top left). Bench thoracic spine mobilisation (top right). Quadruped thoracic rotation with lumbar flexion (bottom left). Bent-over thoracic spine rotation (bottom right)

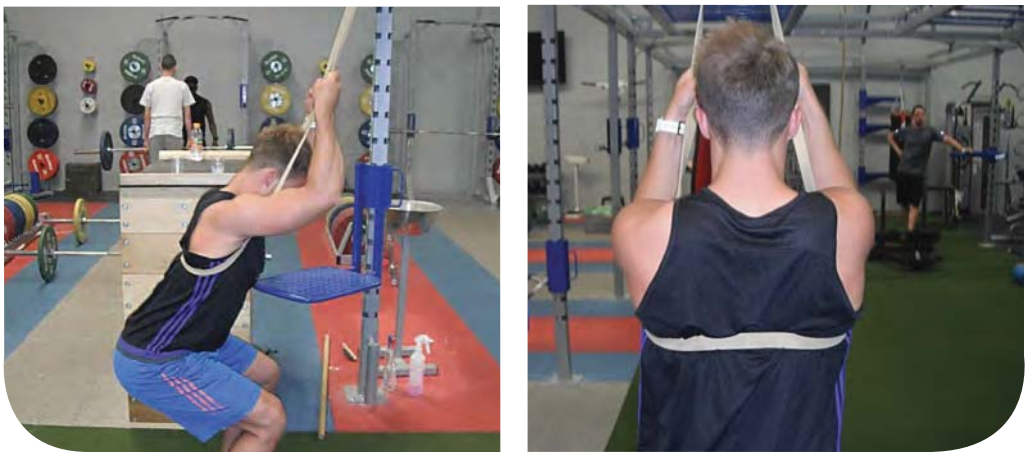


Figure 9. (bottom two)
Facilitating thoracic extension in the squat pattern. A band is used to encourage mid-thoracic extension during a bodyweight squat

'A restriction in either thoracic extension or rotation can prevent correct positioning of the scapula'

mobilisations should place the athlete in a position where their only option is to extend or rotate through the thoracic spine, mobilising the targeted region, and thus limiting compensatory movements. For example, during thoracic extensions performed over a foam roller, an athlete can be placed in a position of hip flexion that encourages lumbar flexion. This position prevents the athlete from extending through the lumbar spine. Figure 8 (on page 27) highlights techniques to mobilise the thoracic spine, while preventing excessive compensation in nearby joint segments.

As with all mobilisation techniques, their effectiveness should be measured by employing a test re-test protocol. For example, when an athlete demonstrates a low capacity to extend the thoracic spine, an intervention aimed at improving mobility should be followed by a re-test of the occiput-to-wall test. Although in the short term only subtle changes may be recorded, this information will provide coaches with an idea of how successful the intervention is. It is also recommended that coaches use this process to identify mobilisations, as well as the acute variables that dictate total volume of application in order to design an effective programme.

MOTOR PATTERN RE-EDUCATION STRATEGIES

When athletes appear to possess the required thoracic extension but do not utilise their capacity (or have regained their mobility following an intervention), a motor pattern re-education programme should be employed to encourage the athlete to extend or rotate through the thoracic spine in order to support upper extremity function. When designing an intervention to improve thoracic motion that supports shoulder function, a number of components should be considered. Firstly, the S&C coach must select an environment where the athlete can complete a movement task with full range of motion in a controlled manner. Initially, the athlete will require additional stability in order to prevent excessive co-contraction patterns that inhibit full range of motion at joint segments. Subsequent progressions are then introduced which gradually reduce stability in these patterns while maintaining movement efficiency.

An example of this is an athlete who compromises the health of the glenohumeral joint by failing to achieve thoracic extension in the catch position of the snatch. In this position, a lack of thoracic extension will potentially result in limiting scapula upwards rotation and posterior tilt, increasing the demand for excessive glenohumeral joint abduction in order to compensate. This athlete may firstly require exercises where they can learn to accomplish thoracic extension in an isolated fashion within the squat pattern. Initially, thoracic extension may need to be assisted. An early stage exercise that forces the athlete into a position of thoracic extension is displayed in Figure 9 (on page before), where the band acts as a crutch by encouraging thoracic extension, as well as offering an additional source for support and therefore increasing stability.

This exercise can be progressed by decreasing the band tension, while continuing to encourage thoracic extension in the bottom position of the squat. This modification not only demands greater intrinsic force development of the thoracic extensor musculature to achieve spinal extension, but also gradually reduces the external support. Further stages of progression would be to place the athlete in an environment that promotes thoracic flexion, which they must overcome to maintain their neutral spine position. This may be accomplished by having the band attached to the floor anteriorly to the athlete, with the other end fixed to the athlete's mid-thoracic region. In this example, the band is orientated perpendicular to the athlete's torso in the catch position. As the athlete completes the squat, the band would function to encourage spinal flexion, thereby increasing the demand for the thoracic extensor musculature to maintain the neutral spine position, further integrating their activation into the motor pattern. At this point, what would likely improve transfer is shifting the emphasis from a local to a more global approach by slowly re-integrating the upper extremity into the squat pattern as it relates to the catch phase of the snatch.

These strategies aim to build the programme around placing the athlete in an environment where they can be successful, slowly increasing the neuromuscular challenge of the movement by manipulating variables that relate to either the task or the environement. For some athletes, only a small period of training time (ie, a single training session) may be required to complete this re-education process before integrating thoracic extension directly into the snatch. Other athletes who may be dealing with limited ability to mobilise the thoracic spine may require a much greater time period to achieve the desired learning effect.

Conclusion

This article has described the effects of limited thoracic spine function and how this can impact on shoulder function. A restriction in either thoracic extension or rotation can prevent correct positioning of the scapula, leading to excessive motion at the glenohumeral joint which increases the risk of impingement syndrome.

To identify causative factors, coaches must use appropriate screening tools to determine if dysfunctions are due to a mobility restriction, or movement pattern abnormality. A range of assessments have been suggested in this article to assist S&C coaches to decide on the appropriate intervention. In addition, mobilisation and motor pattern re-education techniques to increase thoracic spine extension and rotation have been described, which can be easily integrated into an athlete's programme.

AUTHORS' BIOGRAPHIES

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Louis has been coaching elite level athletes for over seven years, previously working for one of London's top universities. He is currently a lecturer in strength and conditioning at St Mary's University, London, teaching on the undergraduate programme. Alongside this role, Louis provides strength and conditioning services to a group of international track and field athletes. Academically, Louis recently completed his MSc in sports rehabilitation.

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