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Neck and Arm Pain Syndromes

**Evidence-informed screening,
diagnosis and management**



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Motor control of the shoulder region

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INTRODUCTION

Motor control around the shoulder, its examination and management, are vast and complex topics. In this chapter, a brief background on motor control theory and the evidence in support of impairments in motor control around the shoulder is provided, together with a summary of the principles of motor learning in the context of shoulder rehabilitation. The focus is on control aspects of the scapulo-thoracic and gleno-humeral joints as directly relevant to shoulder function. While the focus here is on evaluation and management associated with motor control abilities and impairments, evaluation for and management of impairments in pain, range of movement, strength, endurance, power, and technique must also be addressed in a holistic context, with appropriate diagnostic considerations and a thorough biopsychosocial approach. The influence of the remainder of the kinetic chain on shoulder function and of shoulder girdle influence on arm function should also be acknowledged and considered in both examination and management.



MOTOR CONTROL

Motor control theories proposed to explain possible mechanisms responsible for regulating movement address the roles of sensory systems (particularly vision, audition and proprioception) and central processes underpinning posture, movement and stability (Schmidt & Lee 2005,



Shumway-Cook & Woollacott 2007). The concept of a motor programme partially explains the infinite movement options available in performing even simple tasks. A motor programme is considered to be a pre-structured generalized code about the order of events, their relative timing and the relative force required across different tasks. For example, the sequencing of muscle activity and joint motion for shoulder elevation is included in a motor programme of elevation, which is supplemented by rules that specify the parameters related to the particular way the programme is executed according to the task, such as speed (Schmidt & Lee 2005). With increased variability of practice, the motor programme rules are strengthened, improving motor learning. Movement arises from the interactions of perceptual, cognitive and motor processes within the individual and interactions between the individual, the task and the environment (Shumway-Cook & Woollacott 2007). This 'systems' theory approach to motor control emphasizes the importance of assessing for impairments in all processes and being alert to their manifestation in different tasks and environments as a guide to commencing and progressing rehabilitation. Similarly, these interactions necessitate systematic reassessment of treatment interventions to reveal potential influences of one process (e.g. perception) on another (e.g. motor control).

Motor control and joint stability

Motor control and joint stability are closely linked and should be considered as a dynamic process of controlling static position while allowing movement with control (Hodges 2004). Panjabi's now familiar model of three inter-related systems responsible for control of the neutral zone (Panjabi 1992a,b, 1996) forms the basis for much recent work in relation to function and differences in behaviour of different types of muscles. As a result, two groups of muscles have been identified that fulfil different roles – 'stabilizers' or 'local system' and 'mobilizers' or 'global system' (Hodges 2004, Magee & Zachazewski 2007). While this categorization is debated (McGill 2007) and further research is needed to clarify this distinction and its clinical efficacy, we find this construct helpful in focussing assessment and treatment procedures, with excellent results.

Based on a review of the effect of musculoskeletal pain on motor activity and control, Sterling et al (2001) proposed a 'neuromuscular activation model' that identifies dysfunction of synergistic muscle control as a specific and important consequence of pain and injury. This model provides explanation for alteration in muscle activation, proprioception, arthrogenous muscle weakness and muscle fibre changes in the presence of pain. Examination is recommended of all components of the neuromuscular system, including dysfunction of synergistic control, timing of muscle activation, patterns of co-contraction and

proprioceptive control in a patient with musculoskeletal pain, especially pain of any duration. This recommendation, built on the hypothesis related to the relationship between afferent nociceptive input and motor control and the principles of motor learning, forms the foundation of our approach to evaluation and management of patients with shoulder dysfunction.



Evidence of altered motor control around the scapula

Alterations to muscle function around the scapula have been demonstrated in the presence of cervical pain or headaches (Nederhand et al 2000, Falla 2004, Szeto et al 2005, 2009, Falla et al 2007, Jull et al 2008). With respect to the shoulder, a consistent recruitment pattern has been demonstrated in asymptomatic shoulders related to active abduction in the scapular plane (Wadsworth & Bullock-Saxton 1997, Moraes et al 2008) or response to sudden release from an abducted position (Cools et al 2002, 2003) and reaching tasks (Roy et al 2008). Upper trapezius is activated first, followed by serratus anterior, middle trapezius and finally lower trapezius muscles. The temporal characteristics are delayed but not changed by fatigue in asymptomatic subjects (Moraes et al 2008).



A reasonably consistent pattern of decreased activity has been demonstrated in both lower trapezius and serratus anterior and increased activity in upper trapezius in patients with shoulder pain or pathology during different tasks (Glousman et al 1988, Scovazzo et al 1991, Pink et al 1993, Ludewig & Cook 2000, Cools et al 2003, 2004, 2005, 2007a, McClure et al 2006, Roy et al 2008). Kibler (1998) observed that inhibition of lower trapezius and serratus anterior appears to be a non-specific response to shoulder pain irrespective of the pathology. Lower trapezius muscle has a predominance of type I fibres whereas upper trapezius has predominantly type II (Simons et al 1999), with the implication that lower trapezius is best suited for postural and stabilizing roles and upper trapezius for phasic activity. Findings of delayed and/or reduced activity in lower trapezius and serratus anterior in response to shoulder pain coupled with increased activity in upper trapezius, while not universally reported, lend support to this hypothesis. These results support findings from other body regions of a neuromuscular impairment associated with pain in an adjacent joint (Cowan et al 2001, 2002, 2003, Hodges 2004, Colné & Thoumie 2006, Hertel & Olmsted-Kramer 2007, Jull et al 2008).

Altered scapular position is common in association with shoulder pain with typical patterns identified and given various names. Very common is the 'Scapular Downwardly Rotated Syndrome' (Sahrmann 2002), also termed 'Type 1 Scapular Dyskinesis' (Kibler et al 2002, Kibler 2003) and SICK scapula (Scapular mal-position, Inferior medial border prominence, Coracoid pain and



mal-position and dyskinesia of scapular movement) (Burkhart et al 2003). This pattern appears to be associated with insufficiency of the upward rotation force couple and over-activity or increased tone in the antagonist muscles, in particular levator scapulae, rhomboids and pectoralis minor (Kibler 2003).

Serratus anterior and lower trapezius muscles are important components of the scapular upward rotation force couple, particularly above 60° of arm elevation (Bagg & Forrest 1986, 1988). Decreased activity in lower trapezius and serratus anterior associated with arm elevation (Ludewig & Cook 2000, Cools et al 2007a) in patients with sub-acromial pain supports the observation of delayed or reduced upward rotation in the clinical setting. Increased upper trapezius activity under heavier load (Ludewig & Cook 2000) and in the upper ranges of elevation (Cools et al 2007a) possibly reflects a compensation for decreased activity in lower trapezius and serratus anterior and/or an attempt to overcome the increased tone in the antagonists.

A second altered scapular posture, an elevated scapula, is described as Type III scapular dyskinesia (Kibler et al 2002, Kibler 2003). This pattern appears to present in association with either shoulder stiffness into elevation or major rotator cuff dysfunction, such that the deltoid/rotator cuff force couple is disrupted and the humeral head translates superiorly to abut against the undersurface of the acromion. Increased activity in upper trapezius and levator scapulae is dominant.

Not all responses to shoulder pain are consistent (Cools et al 2003, 2004, 2005, 2007a), possibly reflecting the different patterns demonstrated in subgroups within sample populations with the same diagnosis (Graichen et al 2001, Hébert et al 2002, Roy et al 2008). The observation of variations in patterns of muscle activity supports the need to address each patient's impairment during assessment and management.

Altered scapular positioning and scapular plane elevation are frequently associated with increased thoracic kyphosis, cervical flexion or forward head posture (Crawford & Jull 1993, Greenfield et al 1995, Ludewig & Cook 1996, Bullock et al 2005), supporting the kinematic relationship of spinal posture, scapular posture and shoulder elevation. While spinal posture may not be correlated with specific shoulder pathology (Lewis et al 2005a,b), its relationship to shoulder elevation warrants attention in rehabilitation.

Clearly, when considering rehabilitation of the shoulder, attention to the scapular muscle impairments, particularly those related to motor control, is imperative (Ebaugh et al 2005). Equally the shoulder should not be considered in isolation from the cervical and thoracic spine (Jull et al 2008) and the control and movement patterns of the lumbar spine, pelvis and lower limbs (Kibler 1998). While in this chapter the focus is on motor control of the shoulder, the important contributions of these other areas must not be forgotten.

Evidence of altered motor control around the gleno-humeral joint

Evidence related to local stabilizing muscle function around the gleno-humeral joint is less robust, with only two studies reporting on rotator cuff control. David et al (2000) demonstrated that, during isokinetic gleno-humeral rotation, the rotator cuff and biceps brachii when considered as a group, were always activated prior to the superficial muscles, deltoid and pectoralis major, in asymptomatic shoulders and there was always an element of co-contraction, regardless of direction or speed of rotation. The rotator cuff group was also always activated before movement of the isokinetic device's lever arm. This finding supports the hypothesis that the rotator cuff functions in a joint stabilizing role. Delayed activation of the rotator cuff/biceps in individuals with unstable shoulders was also demonstrated in a clinical, but not a research setting.

Hess et al (2005) demonstrated delayed activation of sub-scapularis during a reaction time test into external rotation in throwers with painful shoulders compared to a matched group of asymptomatic volunteers, hypothesizing that sub-scapularis fulfilled a joint stabilization role. However, their testing protocol required use of infraspinatus as a prime mover. Lumbar spine research demonstrates that competing demands on the central nervous system lead to an alteration in muscle use (Hodges 2004) so that when required to function in its primary role, a muscle's secondary stabilizing role is compromised.

Ginn et al (2009) demonstrated from EMG research that the rotator cuff does not function at equal loads through all activities, rather the majority of activation is direction specific. The antagonist cuff muscle was activated at approximately 6% MVC during each of the movements. However, given only 1–3% MVC is required to stiffen a joint (Cholewicki & McGill 1996) their findings do not disprove the stabilization role. There is also a wealth of biomechanical literature that supports a stabilization role for the rotator cuff (Clark & Harryman 1992, Wuelker et al 1995, Burkhart 1996, Kibler 1998, Lee et al 2000), particularly sub-scapularis and infraspinatus/teres minor muscles (Burkhart 1996).

EVALUATION OF MOTOR CONTROL AROUND THE SHOULDER GIRDLE

The assessments described below are used to guide motor control retraining. Impairments in motor control exist within a continuum and manifest as poor postural awareness combined with inability to produce smooth kinematically correct movements through full range without compensation under varying demands of posture, load and speed. While severe impairments will be apparent even in gravity eliminated positions, lesser impairments

will often only be evident in certain ranges of movement, loads (Ludewig & Cook 2000, McClure et al 2001, 2006), speeds (Roy et al 2008) and during distracting tasks (Hodges 2004). Equally side to side comparison provides evidence of bilateral movement dysfunction, possibly indicating pre-disposition to impairment (Hébert et al 2002, McClure et al 2006) and/or more central contribution (Sterling et al 2001) and a poorer prognosis to change. With the aim of converting identified motor control impairments into retraining exercises, each assessment evaluates where (range, posture, load, speed) the patient has control and where that control is lost, attending to all components in the kinetic chain (upper and lower trunk, scapula, gleno-humeral). Assessment is varied with respect to position (against gravity versus gravity eliminated or assisted) to identify the position/function in which control is sufficient to initiate retraining.



Postural assessment

Detailed evaluation of posture allows formation of initial hypotheses in relation to potential impairments in motor control. Postural abnormalities may be associated with movement and control impairments, although an association must not be assumed. Such hypotheses must be tested with movement, resistive and palpatory assessment and specific postural impairment correction during provocative active movements to ascertain the effect (Lewis et al 2005a). Static posture should be assessed in positions relevant to the patient's function and symptom production, not just in a standardized starting position. In addition to visual assessment, the scapular slide test (Kibler 1998, 2003) is a validated measure of scapular resting position, although resting position is not necessarily correlated with function and more objective measures of spinal posture are available (Jull et al 2008).

If an apparent postural impairment is identified, its association to the patient's presenting condition should be tested to determine its direct or indirect relevance by assessing whether alteration of the impairment, either passively or actively, influences the patient's symptoms or sense of 'normalcy'. Although not confirmatory, alteration in response to postural correction and the ability to achieve a corrected position provide an indication of the significance of the positional fault to the symptom presentation, level of awareness or control impairment.



Evaluation of movement impairments and awareness

The focus of this movement assessment is not 'diagnostic' of structural sources of symptoms, but rather on impairments of awareness, movement and control, however always with appropriate caution and monitoring of symptom provocation.

All active movements of the shoulder girdle provide an indication of motor control, in addition to movement awareness, dissociation, relative activity within and between force couples, more so than specific strength or endurance. Therefore, all active shoulder movements should be examined as part of an evaluation of motor control. Any movement impairments are evaluated for their relevance to provocation of symptoms. Assistance with active movement, such as the Scapular Assistance Test (SAT) (Kibler et al 2002, 2006, Kibler 2003) (Fig 21.1 and Box 21.1) to facilitate scapular upward rotation or passive posterior translation for an anteriorly placed humeral head will, for example, often improve movement and lessen symptoms.



Active physiological gleno-humeral movements that are most useful from a motor control perspective include:

- Flexion, abduction, scapular plane abduction: all provide an indication of relative scapular to gleno-humeral contribution, timing of movement of each component and a visual impression of activation of the key muscle groups.
- Gleno-humeral rotations, particularly in 90° abduction/flexion: they demonstrate the ability to move the gleno-humeral joint on a stable scapula and an awareness of dissociation of the arm from the scapula.



Traditional manual muscle tests provide an indication of strength of specific movement directions, not individual muscles, as both stabilizer and mobilizer muscles contribute to the generation of force. Observation of relative control of scapula and gleno-humeral joint during maximal strength tests is useful but does not identify specific individual muscle

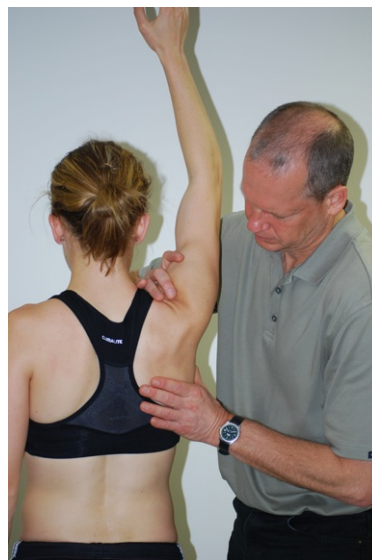


Fig 21.1 Scapular Assistance Test (SAT) (Kibler 2003, Kibler et al 2002, 2006)

Box 21.1 Description / discussion of tests

Figure 21.1

The scapular assistance test involves the therapist providing manual assistance to upward rotation of the scapula during gleno-humeral elevation through flexion, abduction or scapular plane abduction.

**Figure 21.2**

Strength of rotator cuff muscles is more accurately evaluated when the scapula is supported in a retracted position, such that it provides a stable base from which the rotator cuff can work. The therapist maintains the scapula in a retracted position with manual pressure while providing manual resistance to the arm for the relevant rotator cuff test.

**Figure 21.3**

A shoulder shrug in standing with the arms by the side demonstrates the patient's ability to elevate the shoulder girdles to full passive range, the pattern of activation associated with the movement and symmetry between sides. Shoulder shrug is frequently accompanied by significant low cervical flexion and upper cervical extension, scapular elevation combined with protraction and apparent gleno-humeral internal rotation, possibly representing a dominance of levator scapulae over upper trapezius, as the forward poking head lengthens the upper component of the muscle, thus allowing it more leverage to complete the movement at its distal end. The accompanying scapular movement is reflective of the dominance of levator scapulae and pectoralis minor. Correction of this movement pattern leads to an inability to raise the scapulae to their full passive range. A tape or ruler can be used to measure vertical distance between the ear lobe and the shoulder girdle to provide an objective outcome measure.

The hypothesized basis for this test is that, in the elevated arm position, upper trapezius is in its maximally shortened position, so if lengthened in its resting posture, as with a downwardly rotated scapula, attaining the same level of shoulder shrug as with the arms by the side will be difficult. Lack of passive flexibility or overactivity in the levator scapulae, rhomboids or latissimus dorsi will limit passive range of shoulder shrug in this position. An equivalent measure may be taken to compare the range in the two positions.

**Figure 21.4**

Gleno-humeral rotations, particularly in 90 degrees of abduction/flexion, demonstrate the ability to move the gleno-humeral joint on a stable scapula and an awareness of dissociation of the arm from the scapula. Differences in the ability to dissociate in standing and in prone/supine provide indication of the effect of load on the scapular stabilizers and rotator cuff during this task.

This analysis can be made more objective by measuring distance moved by the acromion from its neutral start position during the arm movement. Ideally, movement should

be minimal. Excessive scapular movement leads to greater acromial movement from its resting position.

**Figure 21.5**

Evaluation of awareness of scapular movement can be undertaken using scapular PNF patterns. Given that the movements involved are unfamiliar to the patient, several steps are taken in this evaluation:

- Explain the direction of movement required, using cues such as 'Take the point of your shoulder towards the corner of your eye', while at the same time, touching the corresponding acromial angle and outer corner of the eye and doing the movement with the patient passively, using traditional PNF hand holds and principles. For the opposite direction, 'Take the point of your shoulder blade [while touching it with your fingers] down towards the opposite hip/back pocket' and again, guide the patient in the appropriate movement direction.
- Talk the patient through the movement while performing it passively, ensuring availability of full passive range.
- Ask the patient to assist with the movement, following which unassisted performance determines their ability to replicate it.
- If the patient has difficulty grasping the feel of the movement, further facilitation can be given by means of verbal encouragement, resistance to the movement through range, holds at end of range with slow eccentric contraction and reversals etc (Fig 21.5A).
- In patients with poor awareness or control, the scapula tends to follow a curvilinear path rather than a diagonal, with jerky uncoordinated movement. Frequently, the scapula moves into excessive protraction and anterior tilt when attempting the 'up and forward' direction in particular, as demonstrated in Figure 21.5B. Such an inability to control the movement in a direct diagonal and to the desired end point is an indication that use of PNF as a hands-on facilitation may be indicated in the early stages of rehabilitation.

**Figure 21.6**

The test is performed in side lying, tested arm uppermost, supported on the therapist's arm in approximately 120° elevation, such that the therapist can apply progressively increased resistance into scapular protraction, gleno-humeral elevation and external rotation with the heel of the other hand against the lateral border of the scapula used to assess and resist scapular upward rotation. The activation can be tested isometrically, isotonicly both concentrically and, at higher levels, eccentrically. Poor activation is felt as a sluggish response of the scapula to resistance and/or more 'give' to the movement. The test may be progressed from simply holding the arm while applying resistance to the scapula to resisting protraction and elevation/external rotation on the arm concurrent with upward rotation on the scapula.



Continued

Box 21.1 Description / discussion of tests—cont'd

Figure 21.7

Evaluation in four point kneeling

- Initially, spontaneous posture is noted with respect to spinal, scapular, shoulder and hip alignments and the position maintained for an arbitrary period (e.g. 2 minutes) while observing for fatigue. Typical compensation strategies include locking the elbows into full extension; arms into endrange rotation; dropping the trunk forward, leading to a passive scapular retraction and thoracic extension, increased lumbar lordosis, forward head posture and cervical flexion; elevation of the shoulder girdle towards the ears; scapular winging or tremor of the arm and/or shoulder girdle muscles. Asymmetries from neutral are highlighted to the patient and correction facilitated by passive guidance if necessary. In this context neutral refers to normal spinal curves and scapular posture taking account of patient's individual spinal mobility. The patient's abilities and impairments are then recorded.
- The patient is instructed to shift weight onto one hand, initially without lifting the other arm and then, in conjunction with arm elevation so that the pattern of head on neck, trunk, scapular and arm control can be further evaluated. Again, impairments are recorded. This assessment may be taken through further steps to increase the challenge to match relevant sporting requirements. Raising diagonally opposite arm and leg, in a full push-up position, undertaking the assessment with the legs and trunk on an unstable surface, such as a gym ball or the hand balancing on an unstable surface, such as a slide mat, spin disk or ball all provide additional challenge to the system and may highlight impairments. These steps also integrate the whole kinetic chain so impairments more distant to the shoulder may be identified.

Figure 21.8

Evaluation in four point kneeling

- During evaluation of spinal dissociation, a frequent finding is an inability to position the head in neutral without concomitant thoracic and lumbar extension. Instruction to extend the neck frequently leads to a whole spine extension pattern. A request for pelvic neutral may have a similar effect, with the patient unable to isolate lumbar spine movement.
- With pro/retraction of the scapula, the chest 'drops through' the scapulae on retraction and is elevated between them on protraction. Typically, a patient with shoulder pain is unable to perform this movement independent of thoracic flexion/extension. An inability to fully protract (push up plus position) is also often observed. Education about the impairment and facilitation of an improved movement is undertaken to determine how 'fixed' the impairment is in the patient's motor patterning and therefore, how significant it might be in the context of the presenting problem.

Figure 21.9

The therapist palpates the humeral head with one hand, ensuring no restraint of humeral head movement. This hand feels for humeral head translation or altered quality of movement through each stage of the test. The therapist also observes scapular and spinal control and movement and enquires about provocation of symptoms.

- With the patient's arm by the side, elbow flexed to 90°, neutral forearm rotation, manual resistance is applied slowly through the wrist to an isometric contraction. This contraction is repeated in as many positions as appropriate for the particular patient's presentation. Do not stop in the sequence of positions when an impairment is noted as activity regularly performed at higher range, such as throwing, may lead to better function in this range. The movement is repeated from the neutral start position into the opposite rotation.
- In most instances, at least three elevation positions are tested – neutral, 45–60° elevation and an end position relevant to function – for example, 110° elevation in the scapular plane for a thrower or full elevation for a swimmer, mimicking the catch position.
- The test procedures are repeated using an isotonic contraction through the full available range, first in one rotation and then the other, ensuring that the movement is one of pure rotation.
- If no impairment is detected through any part of the test, it is repeated at higher speed, with an eccentric component, quick reversals or with increased load. Occasionally, the resistance of the therapist's hand is sufficient to facilitate co-contraction. Asking the patient to repeat the test movements with a small weight in the hand may lead to altered humeral head control or the patient may be able to feel when control is lost even if the therapist cannot.
- Once a position of impairment is detected, whether isometrically or dynamically, small variations of positions are evaluated until a position of control is found as close to where control is lost as possible. If impairment on the DRST is prioritized for inclusion in a management plan, this would be the position where training is commenced.

Figure 21.10

- The start position is usually sitting with the arm supported in 60–90° scapular plane elevation, neutral rotation. The start position must be painfree, with a relaxed scapula and relatively neutral spinal position. The therapist palpates the axillary aspect of sub-scapularis with the tips of the middle two fingers, usually from a posterior direction, with the pads adjacent to latissimus dorsi on the posterior axillary wall. Concurrently, the therapist places the pad of the thumb vertically along the tendon of infraspinatus/teres minor so that activation of both components of the force couple can be palpated simultaneously. Finding the sub-scapularis tendon may be difficult on some people,

Box 21.1 Description / discussion of tests—cont'd

especially those with a superiorly translated humeral head or hypertrophy of either latissimus dorsi or pectoralis major. Confirmation of correct positioning is made by gentle resistance into first one rotation and then the other while feeling for increased tone in the relevant tendon.

- Very gentle traction is applied to the humerus and the patient asked to 'draw the arm into the socket'. The therapist palpates both tendons to evaluate levels of contraction while monitoring unwanted activation in other muscles. Manual facilitation by pressure on the tendons may be useful, reinforced by verbal encouragement and visual imagery. This is an unfamiliar task, so initial assessment should be on the non-affected side.
- If co-contraction can be felt but only in association with superficial muscle activity, training is undertaken to reduce the extraneous activity. If no co-contraction can be facilitated, further tactile stimulation and/or imagery may help. For example, the anteriorly unstable shoulder may respond to instruction to 'draw the arm up and back' in association with a traction force combined with gentle internal rotation, thus biasing the facilitation to the external rotators, while the superiorly placed humeral head may respond better to a suggestion to 'draw in and gently push down on my finger in your armpit' in conjunction with pressure on sub-scapularis, although excessive activation of latissimus dorsi and pectoralis major may be the result of this suggestion. Persistence with facilitation and multiple trials may be needed to achieve success. In the future, biofeedback with real time ultrasound is planned to facilitate training.
- Once the co-contraction can be achieved, a benchmark is established to form the basis for a home programme and further training, during which, the patient must be able to find the sub-scapularis tendon and co-contrast without the traction facilitation. An arbitrary 10 repeats

of 10-second hold with slow, smooth build-up and release of contraction is used as a goal before progression. Once this can be achieved, the direction of progression depends on the presentation of the patient. If an athlete whose primary range of poor control is in elevation, progression is quickly made into positions within the DRST where control was lost, whereas the patient with pathology of the rotator cuff or sub-acromial bursa may need much slower and more deliberate co-contraction training before any load is applied to the arm.

Figure 21.11

The patient drives the hands forwards and upwards in a position of elevation, external rotation, elbow extension, thus facilitating the upward rotation component of the movement. Slight tension maintained on a lighter weight theraband into gleno-humeral external rotation ensures that the patient does not drift into internal rotation and scapular position of downward rotation/anterior tilt. The lumbar and cervical spines must be maintained in a neutral position.

Figure 21.12

The theraband is looped over the shoulder and under the opposite foot. The patient catches hold the theraband and steps through the loop. Placing the foot behind in a walk-stand position provides a down & back force on the shoulder, facilitating correct movement of the acromion towards the corner of the eye. Maintenance of chin tuck, arm external rotation and a neutral lumbar spine will all assist correct movement of the scapula.

The reverse 'down & back' pattern can also be trained by placing the theraband over a door and shutting the door while looping the theraband under the axilla. A small towel placed in the axilla makes this more comfortable. The patient stands facing the door so that the theraband pulls the shoulder girdle up and forwards and works the scapula down and back towards the opposite hip.

dysfunction, simply a faulty movement pattern under load. Evaluation and possible correction of scapular position, for example with the Scapular Retraction Test (Kibler et al 2006), during manual muscle testing is essential to determine whether the scapula is fulfilling its stabilizing role (Fig 21.2).

Evaluation of specific motor control impairments around the scapula

On the basis of the evidence and clinical experience, we use the following key movement impairment tests to gain

a broad picture of the ability and level of impairment of the axio-scapular muscles. If movement impairment is noted, its significance is evaluated using the principles outlined above. These assessments are by no means exhaustive, but representative of those commonly found useful.

Shoulder shrug (Roberts 2009)

A shoulder shrug in standing with the arms both by the side and overhead demonstrates the patient's ability to elevate the shoulder girdles to full passive range, the



Fig 21.2 Scapular Retraction Test (SRT) (Kibler et al., 2006)



Fig 21.4 Gleno-humeral rotation on a stable scapula.

pattern of activation and movement symmetry and the effect of the altered muscle balance in different arm positions. A tape or ruler can be used to measure vertical distance between the ear lobe and the shoulder girdle to provide an objective outcome measure (Fig 21.3).

Scapular control through gleno-humeral rotations in prone and supine (Sahrmann 2002)

Gleno-humeral rotations in 90° abduction or flexion demonstrate the ability to move the gleno-humeral joint on a stable scapula and an awareness of dissociation between arm and scapular movement (Fig 21.4). Poor awareness leads to excessive scapular elevation, anterior tilt and protraction during internal rotation and the reverse on external rotation, or simply an inability to maintain a stable position. Measurement of acromial movement from neutral start position during the arm movement makes the test more objective.

Scapular PNF patterns (Voss et al 1985)

Awareness of movement of the scapula in isolation from the arm is difficult. Use of the scapular component of the traditional PNF diagonal arm patterns provides useful information on the kinaesthetic awareness of the scapula (Fig 21.5). Given that this is an unfamiliar movement, it is unreasonable to expect a patient to perform it without some facilitation and education. More detailed description of these tests can be found in Magarey & Jones (2003a).

Evaluation of range and control of scapular upward rotation

Scapular upward rotation occurs actively in conjunction with elevation of the arm. Therefore, the optimal position in which to evaluate activity in the upward rotation force couples is with the arm in elevation greater than 90°, with resistance applied through the arm to gleno-humeral elevation and external rotation and



Fig 21.3 (A) Shoulder shrug with arms by the side. (B) Shoulder shrug with arms in full elevation.

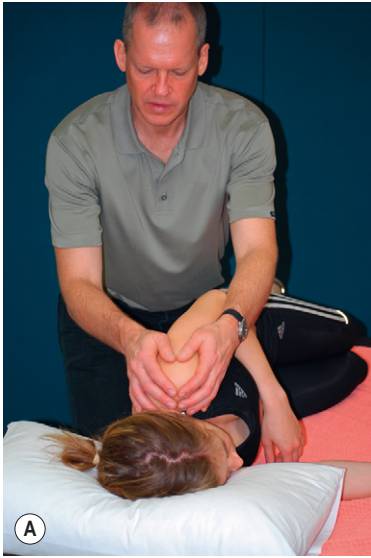


Fig 21.5 Evaluation of scapular movement awareness using scapular PNF patterns. (A) Manual correction and guidance into a more normal movement pattern. (B) Poor movement pattern during scapular movement in an up & forward direction.

through the lateral border and inferior angle of the scapula against upward rotation (Fig 21.6) The stage of the assessment, the quality of contraction of this important force couple, the load applied through the arm and the number of repetitions are all useful clinical outcome measures.



Evaluation of four point kneeling

Four-point kneeling, while itself not particularly functional, is useful for assessing patients' dissociation and control capabilities. The steps can also be applied in prone on elbows or modified plantigrade (i.e. standing with hands supported on table or wall) with the aim of identifying where the patient has control and where that control is lost thereby providing an effective starting



Fig 21.6 Evaluation of scapular upward rotation in gleno-humeral elevation.

position for re-training. Positional and movement impairments of the scapula and humerus are observed and loss of control/position from either identified as the limiting factor.

Steps in the evaluation include observation of spontaneous posture and muscular endurance with a sustained hold, scapular and gleno-humeral control during weight shift from one arm to the other (Fig 21.7), dissociation (the ability to isolate movement of one body part from another) of different regions of the spine and between spine and scapula (Fig 21.8), control of scapular and cervical movements, endurance of pro/retraction while weight-bearing on one or both hands and with trunk movement on a fixed hand. All components can be progressed to more challenging situations, such as with the trunk on a gym ball or hand on an unstable surface, as appropriate for the patient. More detailed



Fig 21.7 Evaluation in four point kneeling: scapular and gleno-humeral control in a single arm loaded position.



Fig 21.8 Dissociation evaluation in four-point kneeling: scapular protraction in a spinal neutral position.

description of these tests can be found in [Magarey & Jones \(2003a\)](#).



Evaluation of specific thoracic extension and control of scapular retraction

The patient's ability to perform thoracic extension in a relatively segmental fashion provides an indication of the priority for its re-training during rehabilitation. One effective evaluation is facilitated inter-segmental extension from C7 to T7/8 over a gym ball, with the trunk remaining in contact with the ball to reduce the lumbar spine contribution. Once relative segmental thoracic extension is achieved, assessment is progressed by addition of scapular retraction and arm movements.

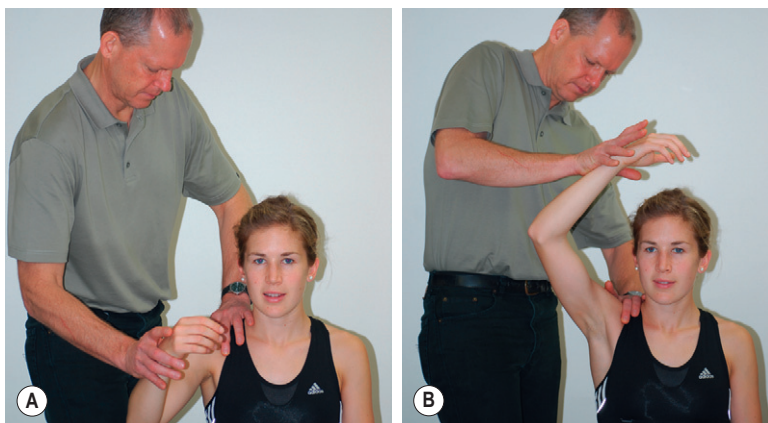


Fig 21.9 Dynamic rotary stability test ([Magarey & Jones 2003a,b](#)). (A) Evaluation of humeral head movement during isometric rotation in low range of elevation. (B) Evaluation of humeral head movement during isometric rotation in high range of elevation.

Evaluation of isolated motor control around the shoulder

Dynamic rotary stability test (DRST) ([Magarey & Jones 2003a,b](#))

The DRST is used to evaluate the rotator cuff's ability to maintain the humeral head centred in the glenoid when loaded through rotation. DRST is predicated on the knowledge that the humeral head should remain centred in the glenoid throughout rotation range in any position of elevation, except at end-range, where coupled translation forces the humeral head to translate ([Harryman et al 1990](#), [Terry et al 1991](#)). When dynamic control is lacking, the humeral head is felt to translate anteriorly, posteriorly or superiorly when the rotator cuff is loaded. In more subtle situations, symptom provocation, alteration in the contraction quality, or compensation elsewhere alerts the examiner to dysfunction without the sensation of humeral head translation. The patient's subjective sensation of 'stability' during testing is also informative.

DRST is undertaken in different parts of the elevation range from neutral towards the patient's symptomatic functional position(s) ([Fig 21.9](#)). The number of positions in which the test is performed depends on the irritability of the condition, the general physical status of the patient, the clarity with which the patient can identify the symptomatic position(s) and the demands placed on the shoulder by the patient. The aim is to find the position(s) in range where the patient has humeral head control as close as possible to the position at which control is lost when isometric and progressively challenging dynamic load is applied to the arm. The amount of resistance added is light/moderate, as the assessment is one of the ability to stabilize, rather than one of rotation strength. All movements are performed in one direction first rather than alternately as patients find this easier. If lack of control is identified, rehabilitation can be undertaken starting from positions of control to facilitate



Fig 21.10 Dynamic relocation test (Magarey & Jones 2003a,b)

activation of the rotator cuff with progression to more challenging positions. More detailed description of this test may be found in Magarey & Jones (2003b).

Dynamic relocation test (DRT) (Magarey & Jones 2003a,b)

The DRT is a test of the ability of the rotator cuff, particularly the lower elements, to stabilize the humeral head in the glenoid by means of co-contraction against a de-stabilizing load. Once the ability to isolate the co-contraction has been determined in an optimal position, it can be evaluated in different positions and during different tasks. If a patient is unable to achieve more than the very basic levels of the DRST, assessment should start with the DRT. The principles of testing are similar to those for the cranio-cervical flexion test (Jull et al 2008) and trans-versus abdominis activation (Hodges 2004).

Patient education about test performance is important as it is an unfamiliar task. Use of diagrams and/or anatomical models is helpful so that the patient understands that the movement required is one of a subtle 'drawing in' of the humeral head to the glenoid via co-contraction of infraspinatus/teres minor and sub-scapularis with minimal involvement of the superficial muscles, in response to a gentle longitudinal movement applied to the arm (Fig 21.10). Occasionally, patients' ability to co-contract is enhanced in a loaded, closed kinetic chain position. More detailed description of this test may be found in Magarey & Jones (2003b).

MANAGEMENT OF MOTOR CONTROL IMPAIRMENTS AROUND THE SHOULDER GIRDLE

Motor learning refers to the processes associated with practice or experience that lead to the acquisition/reacquisition of relatively permanent movement capability

(Schmidt & Lee 2005, Shumway-Cook & Woollacott 2007). Rehabilitation strategies should be tailored to the individual's goals and specific neuromuscular impairments and motor control capabilities that may vary in different body segments and over different tasks.

While the Fitts & Posner (1967) (cognitive, associative, autonomous) model of motor learning is perhaps more familiar, Vereijken et al (1992) described another three-stage (novice, advanced, expert) theory of motor learning that accounts for reductions in body degrees of freedom seen in child development and new skill acquisition in general. Given that much research around disruptions to motor control relates to freezing of degrees of freedom (Cowan et al 2001, 2002, 2003, Hodges 2004, Colné & Thoumie 2006, Hertel & Olmsted-Kramer 2007, Jull et al 2008), we feel this model complements and adds to the useful model of Fitts & Posner (1967). The novice stage involves the learner freezing degrees of freedom by co-contracting agonists and antagonists to constrain a joint to simplify the movement, as with the rigid bracing of the wrist when first learning to use a hammer. Degrees of freedom are progressively released through the advanced and expert stages enabling movement at more joints and more sophisticated muscle synergies across multiple joints until smooth, coordinated movements are performed. This theory offers rationale for the clinical effectiveness of strategic posturing and external support commonly used in early stages of rehabilitation such as re-training co-contraction of sub-scapularis and infraspinatus initially with the arm supported in a stabilized scapular and gleno-humeral neutral position. Decreasing degrees of freedom requirements at the scapula through external support of the table and neutral positioning simplifies the task allowing the patient to focus on the correct activation.

Shoulder complex rehabilitation exercises should be individualized to specific impairments identified from the examination as potential contributors to the patients' activity (e.g. shoulder elevation or throwing) and participation limitations (e.g. activities of daily living or sport) (Graichen et al 2001, Hébert et al 2002, Roy et al 2008). The focus in relation to motor learning theory and research in this chapter is limited to retraining of skills with which patients are already familiar, not learning new skills. While this implies commencing with the associative/advanced stage of motor skill development, pre-existing impairments in posture and movement patterns commonly require that attention is given to the cognitive/novice stage to ensure understanding and correct performance (e.g. retraining shoulder elevation with less scapular protraction). Awareness training is generally started in neutral positions while control training is commenced from neutral or a position close to the position of impairment where the action/hold can be performed correctly.

Patient understanding and motivation, goal setting, practice and feedback (Schmidt & Lee 2005, Shumway-Cook & Woollacott 2007, Sousa 2006) facilitate motor learning. Understanding, where explanations are meaningful to the individual, enhances patient motivation, attention and

learning. The more thoroughly information is processed, the deeper the learning and more likely the transfer to new situations outside the therapeutic setting (Sousa 2006). Explanations of assessment findings and management recommendations, linked to research and successful clinical outcomes, use of anatomical pictures and models and opportunities to ask questions and summarize main points all promote deeper learning.

Goal setting also facilitates motivation and learning. Specific, absolute goals of moderate difficulty produce better performance than either vague (e.g. 'do your best') (Kyllo & Landers 1995, Schmidt & Lee 2005) or no goals. Specific goals, both short and long term assist patient focus and facilitate performance while providing a reference for monitoring progress (Kyllo & Landers 1995).

Practice is recognized as the single most important variable influencing learning with large improvements early and smaller improvements later (Schmidt & Lee 2005, Shumway-Cook & Woollacott 2007). While synaptic connections are strengthened through experience and repetition (Spitzer 1999), success during exercise enhances learning necessitating exercises chosen are ones that can be successfully achieved with good kinematic control and no symptom aggravation. Successful exercise performance in one position is progressed to other positions or activities, leading to improved and more generalized learning. The basic premise is that with practice, people develop rules about their motor behaviour, not individual movements, and these rules are more effectively learned for use in other, even novel tasks, if the experience is varied rather than constant.

Augmented feedback regarding performance of a movement or exercise is considered a critical variable to motor learning; second only to practice itself (Schmidt & Lee 2005). Performance feedback can be provided visually, as with video, real-time ultrasound (RTUS) or EMG-based biofeedback or verbally, typically highlighting some aspect of the movement pattern that is difficult to perceive (e.g. recognition of spinal posture/movement during shoulder elevation). Inherent feedback refers to sensory information directly available to the individual during or resulting from the execution of a movement. Understanding when control is lost is essential for home motor control exercises to ensure exercises are not continued past this point potentially reinforcing incorrect movement patterns. For example, while the patient cannot see the loss of scapular control, by drawing their attention to their scapula they can be taught to recognize the local sensation associated with control and loss of control and thereby learn to continue the exercise only to the point when that sensation occurs.

Management of shoulder motor control through patient examples

Two brief patient cases are presented as examples of implementation of the suggestions above and to highlight clinical reasoning and implementation of motor learning principles.

Case 1

- Tom – 19-year-old, left hand dominant, elite baseball player with a painful shoulder with throwing

Tom presented with deep, moderately severe superior shoulder pain associated primarily with the late cocking phase of a throw. The onset was gradual through the previous baseball season and he was keen to address it in the off-season. There were no red flag issues to consider, no apparent frank rotator cuff or labral pathology, cervical or neurodynamic involvement.

Tom had good range of movement but poor awareness of dissociation of different regions of his spine and between spine and scapula, leading to poor ability to stabilize scapula or arm. He stood with poor spinal posture, particularly thoracic kyphosis and forward head posture. Active assisted correction was possible but could not be maintained. His scapula was downwardly rotated and anteriorly tilted so that his arm hung in medial rotation. His ability to dissociate in four point kneeling was inadequate as he was unable to sustain good scapular position without fatigue related compensations. Increased 'give' to resistance on the lateral scapular border was evident on upward rotation of his affected side (Fig 21.7). DRST demonstrated poor isometric control of his humeral head in 110° scapular elevation with both rotations, the position relevant to his throwing, and at 90° with slow isotonic rotations. With facilitation, Tom was able to achieve good contraction and control in neutral with the DRT.

Tom's management consisted of education about the relevance of his postural and movement impairments to his throwing pain, followed by spinal and scapular postural correction and dissociation training in both sitting and four-point kneeling, later progressed to standing and positions relevant for throwing. Re-training upward rotation of his scapula, with hands-on facilitation/feedback was followed by a home programme, ensuring maintenance of neutral spine, gleno-humeral external rotation and elbow extension as he drove forwards through his hands (Fig 21.11). As Tom improved, training was progressed to closed kinetic chain activities such as slide board in four point kneeling and push-up position, concentric and eccentric load, always focussing on good positioning.

Isolation training for gleno-humeral stabilization was not warranted as Tom was able to learn the technique quickly and integrate it into the DRST, to which training was directed immediately close to positions of lost control, both isometrically and isotonicly, stopping when he felt humeral head translation or lost control of his scapular position, both of which required explicit sensory recognition training for him to recognize. Over time, he increased the speed and range of movement, as required for throwing, and later increased load.

Attention to Tom's throwing technique and the rest of his kinetic chain was an integral part of his management, with strengthening and skill training built around



Fig 21.11 Home exercise for re-training scapular upward rotation.

dynamic control. If any given strengthening exercise resulted in loss of control, the task was judged too challenging and modified in position or load. For each task, frequent practice in as many different environments as practical was encouraged to facilitate motor learning (Schmidt & Lee 2005). Over time, lengths of hold, load, and repetitions were increased and other cognitively distracting tasks added to challenge the neuromuscular system further.

Tom was provided with thoracic extension facilitation training over the gym ball, learning inter-segmental thoracic extension and then loaded endurance exercises into extension. As a result of the postural training and maintenance of good cervical posture throughout these exercises, inclusion of formal cranio-cervical flexor training was not necessary. Later progressions were added to further challenge his spinal control and endurance in conjunction with arm movements.

The need to lose co-contraction is part of the autonomous/expert stage of learning associated with skilled activity (Shumway-Cook & Woollacott 2007) such that the task becomes a feed-forward mechanism not a feedback one. As Tom's control of the DRST position improved and he returned to throwing, it is likely that he lost the majority of the co-contraction while refining his technique. Loss of co-contraction in skilled pitchers (Glousman et al 1988) and elite swimmers (Carr et al 1998) compared to untrained controls supports the need to increase degrees of freedom with development of skill (Vereijken et al 1992). However, intermittent but regular co-contraction training is recommended as clinical

experience demonstrates a tendency to lose this ability with the potential to lead to higher risk of injury. Such control is still required for activities requiring high degrees of accuracy (Gribble et al 2003).



Case 2

- Joan – 59-year-old, right hand dominant, office worker with MRI confirmed full thickness rotator cuff tear involving supraspinatus and a small portion of infraspinatus, coupled with a thickened swollen sub-acromial bursa.

Joan presented with sharp severe left sub-acromial pain on quick movements, an inability to raise her arm above 90° elevation because 'it won't go' and difficulty sleeping because of pain. Three weeks previously, her dog pulled suddenly on the leash and she felt something 'give' in her shoulder. Joan had a history of 'nuisance value' discomfort in her shoulder and neck pain with prolonged computer use. She had difficulty with hand behind back activities, brushing her hair and reaching to the top cupboard because of painful limitation of movement. However, the pain settled quickly. There were no neurological symptoms, VBI issues or red flags. As a result of painful restricted range, Joan's motor control assessment was limited.

Joan's key postural impairments included increased thoracic kyphosis, forward head posture, elevation of her left acromion compared to right, apparent increased tone in both levator scapulae and upper trapezius, wasting of supraspinatus. Correction of spinal posture was impossible due to low cervical/upper thoracic stiffness on extension. Active shoulder elevation of 80° led to immediate humeral superior translation and scapular elevation, while assistance to scapular upward rotation gained a further 30° before pain increased. Pain and weakness prevented Joan from holding this position.

Joan's movement awareness on scapular PNF patterns was poor, even with facilitation. DRT was taught initially on her right shoulder where she could activate the rotator cuff well; however, she had great difficulty in the left shoulder, eventually able to create only a weak pain-free co-contraction, sustained for 3–4 seconds.

Joan's rotator cuff tear was not large but extended into infraspinatus, such that it disrupted the biomechanics of the shoulder (Burkhart 1996). Therefore, the lower rotator cuff force couple was unable to control superior humeral migration during active elevation. The motor control approach required focus on scapula and rotator cuff concurrently as the movement impairment was so closely linked. Joan's accessory movement of the lower cervical and upper thoracic spine revealed significant stiffness which also contributed to her loss of shoulder elevation.

The priorities for Joan's treatment were very different to those for Tom. Isolated rotator cuff training with the dynamic relocation manoeuvre was appropriate in



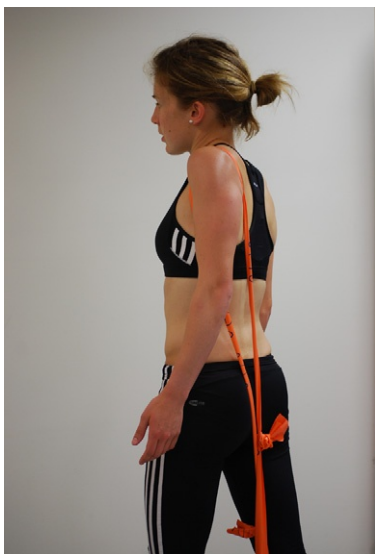


Fig 21.12 Home exercise for re-training scapular movement awareness in the PNF pattern of 'up & forward'.

conjunction with re-training scapular movement patterns. Passive mobilization and mobility exercises improved her spinal range following which awareness and inter-segmental control were facilitated with training. Joan's poor cervical posture and previous cervical pain meant that cranio-cervical flexor evaluation and training were appropriate and integrated (Jull et al 2008).

Scapular PNF patterns were used to facilitate improved scapular awareness and movement. Tactile and verbal stimulation of correct movement was complemented with a home programme (Fig 21.12).

Dynamic relocation training was initiated in a pain-free neutral position, gradually building her capacity to 10 sets of 10-second holds of good quality contraction. Training was then progressed into increased ranges of elevation, always with the arm supported and pain-free. Only when Joan could perform 10 sets of 10 holds in each position was she progressed to taking the weight of her arm. Gradually, she was able to support her arm in each training position and could start to work into functional positions through elevation with controlled scapulo-humeral and gleno-humeral movement.

Once Joan could perform the PNF patterns well, side-lying scapular upward rotation training was instigated in the increased range available, initially with no load through the arm and later, adding a protraction load but upward rotation stimulus only to the lateral scapular border, with progression focussed on increased elevation range rather than load, again with an associated home programme.

Tom's problems were largely a result of poor movement awareness and technique combined with inadequate postural awareness, endurance and explosive power for throwing. Joan's poor movement patterns were much more entrenched and associated with spinal stiffness, pathology within the tissues and provocation of pain. Reduction in pain and increase in range likely resulted at least in part from improved spinal and shoulder girdle movement patterns plus reduced superior humeral translation, reducing the compressive force through the inflamed sub-acromial bursa. As a result of her initial poor ability to control the humeral head position, isolation training of the rotator cuff was warranted, combined with progressive scapular training. Progression was slow whereas for Tom, it was quick.

The training programmes chosen incorporate exercises from or are similar to those recommended by Cools et al (2007b) and Kibler et al (2006). While not exhaustive, this approach to management of poor motor control is effective and applicable across a range of presentations of patients with shoulder pain.



CONCLUSION

Our approach to motor control evaluation and management has not been validated in formal research but is based on strong evidence, sound clinical reasoning and experience. While we readily acknowledge that motor control re-training extends beyond re-gaining control of the neutral zone, for the purposes of this chapter, the main focus has been on the early stages as progressive loading is covered in Chapter 22. Building more functional re-training on the basis of sound motor control enhances the benefits of more advanced training and improves chances of successful management.



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