Stability and Movement Dysfunction Related to the Elbow and Forearm

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Review of Movement Dysfunction

Researchers and clinicians have explored movement and function for many years (Janda 1994, O'Sullivan et al. 1997, Hodges 1999, Richardson et al. 1999, Jull 2000, Comerford & Mottram 2001a, Sahrmann 2001). Identifying and correcting stability dysfunction is an important component in managing musculoskeletal pain problems and in recent years this has been well documented in the literature (O'Sullivan et al. 1997, Richardson et al. 1999, Jull 2000, O'Sullivan 2000, Comerford & Mottram 2001a,b,). Stability and stability dysfunction are poorly defined in the literature. Stability here is best described as central nervous system modulation of efficient low threshold recruitment and integration of local and global muscle systems. This integrated activity has the function of controlling the inter-segmental articular neutral zone, providing low threshold co-contraction to control posture and alignment, and provide co-ordinated patterns of recruitment to both concentrically produce range of motion and eccentrically decelerate motion, thus control excessive range of motion. Therefore, instability can be defined as inefficient low threshold recruitment or unco-ordinated integration of the local and global stability muscle systems. Much of the literature has focused on the spine and little has focused on stability dysfunction in the peripheral joints. This paper attempts to identify stability dysfunction related to the elbow and forearm.

Local and global muscles systems are required for efficient stability function (Bergmark 1989). The local muscles are deep and are responsible for control of articular translation and inter-segmental motion. Their activity is independent of direction and is often anticipatory to movement to provide protective stiffness during motion. These muscles do not change length significantly during normal functional movements. The global muscles, on the other hand, are responsible for alignment and range of motion. They change length significantly during functional movements, with concentric shortening to produce range of motion, isometric co-contraction to maintain position or alignment and eccentric lengthening to decelerate movement and protect against excessive range of motion. All the global muscles are direction dependent and as such are influenced by antagonistic muscle activity. Neither the local or global muscle systems in isolation can control functional stability.

Muscle dysfunction can be identified in both local and global systems (Comerford & Mottram 2001a). Recent research has demonstrated that dysfunction in the local muscle system is specific to particular muscles. These muscles include the segmental fibres of psoas major (Dangaria & Naesh 1998), deep cervical flexors (Jull 2000), segmental fibres of lumbar multifidus (Hides et al. 1994), transversus abdominis (Hodges & Richardson 1996, Richardson et al. 1999), vastus medialis obliquus (Stokes & Young 1984, Cowan et al. 2001), and upper trapezius (Wadsworth & Bullock Saxton 1997). Local muscle system dysfunction presents in four ways (Comerford and Mottram 2001a):

i) uncontrolled segmental translation,
ii) segmental decrease in cross sectional area,
iii) altered patterns of motor recruitment and
iv) altered timing of motor recruitment.

Global dysfunction is related to alterations in relative length and force (active or passive) relationships between the global muscles.

Global muscle system dysfunction presents in three ways (Comerford and Mottram 2001a).

i) alteration of length-tension characteristics to reflect habitual use or misuse (Gossman et al 1982, Richardson and Simms 1991, Wiemann et al 1998).
ii) altered recruitment patterns (imbalance) between synergistic and antagonistic muscles (Janda 1983 1994, O'Sullivan et al 1998, Jull et al 1999, Sahrmann 2001,).
iii) direction dependant relative stiffness - relative flexibility (Woolsey et al 1988, Singer et al 1993, Hamilton and Richardson 1998, Sahrmann 2001,).

The loss of ideal local or global control may result in abnormal stress or strain being imposed on the joint, the supporting soft tissue structures, the related myofascial tissue or neural tissue. As a result of this dysfunction, pain and pathology may occur (Panjabi 1992, Cholewicki & McGill 1996, Comerford & Mottram 2001a, Sahrmann 2001). Although pain and dysfunction are related, the pain may resolve but the dysfunction will often persist (Hides et al. 1996, Richardson et al 1999). This predisposes to increased incidence of recurrence (Hides et al. 2001). Clinical situations in which movement dysfunction is a major contributing factor to musculoskeletal pathology of mechanical origin include: postural pain, pain of insidious onset, static loading or holding pain, overuse pathology (low force repetitive strain or high force / impact repetitive strain), recurrent pain patterns and chronic pain (Comerford & Mottram 2001a). These presentations are commonly seen in patients with elbow and forearm pain (Gibbons 2001).

Movement dysfunction can present in two ways (Comerford & Mottram 2001a). It can present as dysfunction at an articular level, which is assessed as abnormal articular translational motion. The dysfunction can also present at a myofascial level in functional movements, which is observed as abnormal myofascial extensibility and recruitment. This results in abnormal functional or physiological movements. Articular and myofascial dysfunction commonly occur together. The inability to dynamically control articular translation and myofascial dysfunction at a motion segment may present as a combination of uncontrolled movement or **'give'**, which is usually associated with (or the result of) a loss of motion or **'restriction'**. 'Give' is defined as a lack of active low threshold muscle control in the local or global muscle systems. This give can present as lack of control of hypermobile range (e.g. elbow hyperextension associated with a lack of control of brachialis and brachioradialis), however it frequently presents as a lack of control of normal range. For example, the role of extensor carpi ulnaris (ulnar head) is to control or resist wrist flexion (refer to table 2). In activities where wrist flexion is habitually sustained or used within the normal range, extensor carpi ulnaris may lack dynamic control (e.g. with keyboard use). It is important to understand that although give most commonly presents as compensation for restriction or active habitual overuse of certain mobilizer muscles, a give may be present without a restriction due to extrinsic trauma. Although uncommon, a restriction may be present without compensation however there will be a certain loss of function.

The give can develop to compensate for an articular or myofascial restriction in order to maintain normal function. For example, excessive anterior translation of the humeral head with associated lack of subscapularis control may compensate for a myofascial restriction of gleno-humeral medial rotation (short infraspinatus and teres minor). Gleno-humeral lateral rotation and associated lack of control of subscapularis and teres major may compensate for a limitation of forearm supination (restriction of superior radio-ulna joint or short pronator teres). Occasionally the give develops because excessive range of movement is habitually performed (without compensating for restrictions). This may be due to an active process of overuse and resultant shortening of a particular muscle that hold a joint towards end range (away from neutral). For example a posture of elbow flexion and wrist radial deviation may be the result of active overuse of extensor carpi radialis longus during racquet sports. The give may also be the result of a passive process where sustained postural positioning holds the joint or region away from end range. For example, during typing the wrists often 'hang' in wrist flexion for sustained periods. Give may even be unrelated to habitual movements and postures and be the sole result of trauma, eg. a fall on an outstretched arm and hand damaging the radio-carpal ligaments resulting in translational instability.

In the movement system, the site of greatest give (or compensation) is the **'site of stability dysfunction'**. The uncontrolled segment or region of give is the most likely site of the source of pathology and symptoms of mechanical origin. The uncontrolled movement abnormally loads myofascial, articular, neural or connective tissue structures. For example, uncontrolled or habitual wrist flexion increases compression of the carpal tunnel and subsequently median nerve pathology &/or symptoms may develop. Likewise, excessive dominance of extensor carpi radialis longus (relative to brachialis and brachioradialis) as an elbow flexor, excessively loads the common extensor origin at the elbow may result in lateral elbow pain and pathology . The direction of give relates to the direction of tissue stress or strain and pain producing movements and it is important not only to find the site of give but also the direction of give. This articular and myofascial dysfunction has significant clinical implications in patients who present with pain, disability and dysfunction around the elbow and forearm. An understanding of this stability dysfunction is described here.

Elbow Muscle Anatomy and Classification of Function

A clinically useful model of muscle classification has been developed figure 1 (Mottram and Comerford, 1998; Comerford and Mottram 2001a). This functional classification divides muscles into three groups: local stabilizers, global stabilizers and global mobilizers. The functions of these muscles have been considered in Table 1. Functional classification will now be considered to muscles around the elbow and forearm.

Stability muscles - local

Muscles are classified as local stability muscles based on the function and characteristics outlined in Table 1. The classification of elbow and forearm muscles is detailed in Table 2.

Supinator

Supinator has both radial and ulnar fibres; the ulna having both superficial deep and fibres (Gibbons 2001, Gibbons et al. 2001) (Figure 2a,b). Basmajian & Griffen (1972) used deep

Local Stability Muscle	Global Stability Muscle	Global Mobility Muscle

Figure 1. Classification of muscle function. *Reproduced with kind permission of Kinetic Control*

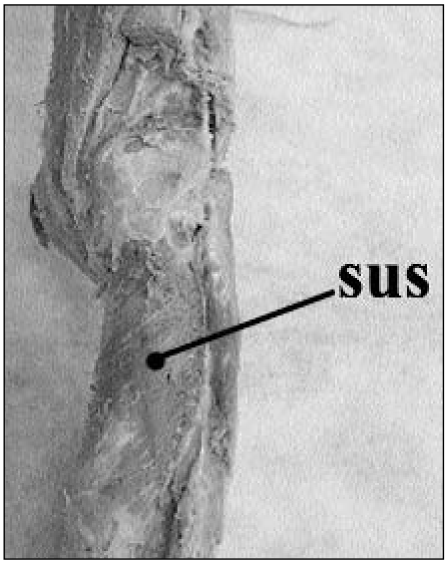

Figure 2a. Superficial ulnar fibres of supinator (SUS). The superficial ulnar fibres originate on the lateral aspect of the supinator crest of the ulna and run downward and laterally to wrap around the upper 1/3 of the radius.

needle electromyography (EMG) in the deep ulnar fibres of supinator and found it was the first muscle active during supination and was continuously active during pronation, suggesting a stability and control role. Pronator teres activity was negligible during supination suggesting a mobility role related to range of motion during pronation.

The radial and deep ulnar fibres of supinator are probably inefficient at producing range or force of supination. Based on the anatomy, it appears the radial fibres can provide a local stability role for the humero-radial joint. The deep ulnar fibres of supinator bind the proximal radio-ulnar joint together and are probably less capable of contributing significantly to supination. From the EMG and anatomy research, the deep ulnar fibres of supinator appear to be best suited for a local stability role for the proximal radio-ulnar joint (Gibbons 2001, Gibbons et al. 2001).

Pronator Quadratus

Pronator quadratus has both superficial and deep fibres (Gibbons 2001, Gibbons et al. 2001) (Figure 3). Due to their short lever arm the deep fibres will contribute minimally to force and range of movement. The function of the deep fibres has been reported to bind the distal radio-ulnar joint together (Moore 1992). Pronator quadratus is the first muscle active in pronation and is active at all joint angles and speeds (Basmajian & Travill 1961). Basmajian & Deluca (1985) report that the deep fibres are also active during supination (De Sousa et al. 1957, 1958) suggesting a stability role. Pronator teres is normally active in rapid or forced pronation (Basmajian & Travill 1961) suggesting it has more of a mobility role. The anatomical structure, lack of siginificant role in movement production, and the EMG research

Table 1. Muscle function and characteristics

LOCAL STABILIZER	GLOBAL STABILIZER	GLOBAL MOBILIZER
• ↑ muscle stiffness to control segmental motion • Controls the neutral joint position • Contraction = no / min. length change ∴ does not produce R.O.M. • Activity is often anticipatory (or at the same instant) to functional load or movement to provide protective stiffness prior to motion stress • Activity is independent of direction of movement • Continuous activity throughout movement • Proprioceptive input re: joint position, range and rate of movement	• Generates force to control range of motion • Contraction = eccentric length change ∴ control throughout range especially inner range ('muscle active = joint passive') and hyper-mobile outer range • Low load deceleration of momentum (especially axial plane: rotation) • Activity is direction dependent	• Generates torque to produce range of movement • Contraction = concentric length change ∴ concentric production of movement (rather than eccentric control) • Concentric acceleration of movement (especially sagittal plane: flexion / extension) • Shock absorption of load • Activity is direction dependent • Non-continuous activity (on : off phasic pattern)

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Table 2. Classification of forearm and elbow muscles (muscles acting solely on the hand are not considered)

LOCAL STABILIZER	GLOBAL STABILIZER	GLOBAL MOBILIZER
Anconeus (deep fibres) **Pronator Quadratus** (deep fibres) **Supinator** (deep radial & deep ulnar fibres)	**Brachialis** **Brachioradialis** **Triceps Brachii** (medial &lateral heads **Anconeus** (superficial fibres) **Supinator** (superficial ulnar fibres) **Pronator Quadratus** (superficial fibres) **Extensor Carpi Ulnaris** (ulnar head) **Flexor Carpi Ulnaris** (ulnar head) **Abductor Pollicis Longus**	**Biceps Brachii** (long & short heads) **Triceps Brachii** (long head) **Extensor Carpi Radialis Longus** **Extensor Carpi Radialis Brevis** **Extensor Digitorum** **Extensor Digiti Minimi** **Extensor Carpi Ulnaris** (humeral head) **Extensor Indicis** **Extensor Pollicis Brevis** **Extensor Pollicis Longus** **Pronator Teres** **Palmaris Longus** **Flexor Digitorum Superficialis** **Flexor Digitorum Profundus** **Flexor Carpi Radialis** **Flexor Carpi Ulnaris** (humeral head) **Flexor Pollicis Longus**

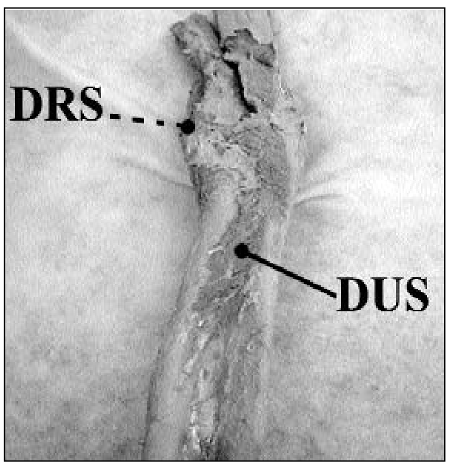

Figure 2b. Deep ulnar fibres of supinator (DUS) and the deep radial fibres of supinator (DRS). The deep ulnar fibres run parallel to the radio-humeral joint and bind the superior radio-ulnar joint together. These fibres are continuous with the interosseous membrane and probably act as a local stabiliser of this joint by controlling segmental movement. The deep radial fibres (dissected out) attach proximally and laterally to the medial epicondyle, the annular and radial collateral ligaments. These fibres are short, are orientated longitudinally and are suited to stabilize the radio-humeral joint.

suggest that the deep fibres of pronator quadratus have characteristics of a local stability muscle (Gibbons 2001, Gibbons et al. 2001).

Anconeus

Anconeus has both deep and superficial fibres (Gibbons 2001, Gibbons et al. 2001) (Figure 4). Anconeus has been reported to be a stability muscle, but its exact role has been unknown (Basmajian & Griffen 1972, Le Bozec et al. 1980a; Maton et al. 1980). Anconeus is continually active during pronation, supination and elbow extension (Basmajian & Griffen 1972). It is activated prior to the medial head of triceps during elbow extension and its recruitment is important for low load and during slow movements (Le Bozec et al. 1980b). These fibres can act as a local stabilizer for the humero-ulnar and humero-radial joints (Gibbons 2001; Gibbons et al. 2001).

Stability muscles - global

Muscles are classified as global stability muscles and global mobility muscles based on the function and characteristics outlined in Table 1. The classification of elbow and forearm muscles is detailed in Table 2. The global stability muscles of the elbow and forearm, eg. brachialis, the superficial fibres of anconeus, superficial ulnar fibres of supinator, generate tension to produce stability throughout range. Supinator produces forearm rotation (supination) and controls eccentric pronation at the proximal radio-ulnar and humero-radial joints. Brachialis has been termed the 'work horse' of the elbow flexors (Basmajian & Latif, 1957). It is active during all elbow flexion movements in pronation and supination. This has been postulated to be because it's line of pull is not altered by forearm rotation. It is also positioned to eccentrically control elbow extension.

Mobility muscles - global

The third group, the **global mobility muscles** of the elbow and forearm are listed in Table 2 and examples include biceps brachii and pronator teres. Biceps brachii shows little activity at low loads or speeds of elbow flexion or supination. Primarily it is recruited at higher speeds or when loaded (Basmajian & Latif 1957). It is also recruited when decelerating elbow flexion at high speeds (Maton et al. 1980). Pronator teres is recruited at higher speeds and under load (Basmajian & Travill 1961) and does

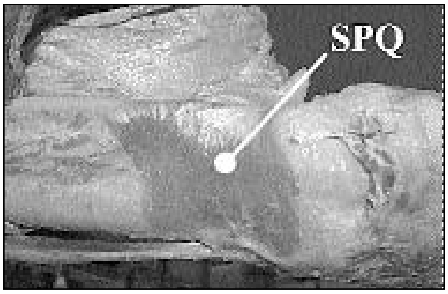

Figure 3a. Superficial fibres of pronator quadratus (SPQ). The superficial fibres originate from the anterior surface of the distal 1/4 of the ulna and run to the anterior surface of the distal 1/4 of the radius. Its superficial fascia is continuous with the anterior fascia of the carpus.

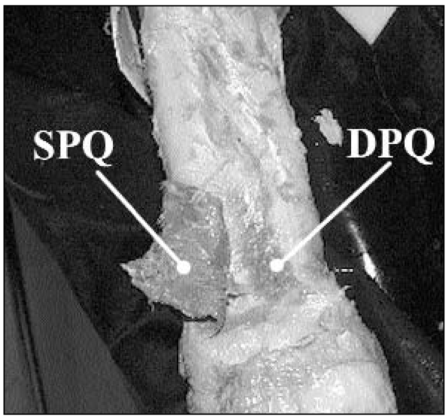

Figure 3b. Deep fibres of Pronator Quadratus (DPQ). The deep fibres are continuous with the interosseous membrane and are less than 1cm in length so will contribute minimally to movement. (The superficial fibres are reflected back).

not contribute significantly to pronation under low load or low speeds.

The lateral and medial heads of triceps may be classified as a mono-articular muscle, while the long head may be considered bi-articular. Basmajian & Griffen (1972) used fine wire electrodes in the middle belly of the medial head of triceps, pronator teres, supinator and anconeus. They reported a close synergy between anconeus, supinator and the medial head of triceps and concluded these must be involved in joint stabilization. Le Bozec et al. (1980b) used surface electrodes on all three heads of triceps and on anconeus. They reported a close relationship between anconeus and the lateral head of triceps during deceleration of elbow flexion. Although this data is somewhat conflicting, the medial and lateral heads of triceps appear to have a stability role and may be classified as global stabilizers based on their anatomical disposition.

Movement Dysfunction of the Elbow & Forearm

In recent years the characteristics that identify dysfunction in these three muscle groups (local stabilizers, global stabilizers, global mobilizers) have been illustrated (Mottram & Comerford 1998, Comerford & Mottram 2001a) and are summarized in Table 3.

Stability dysfunction can be identified by evaluating the function of the local and global stability muscles (Comerford & Mottram 2001a,b). One useful way to assess for dysfunction is to look at the movement patterns and observe for uncontrolled movement or give. The assessment of forearm movement dysfunction can be made by using four base tests. These are:

(1) Elbow flexion - extension (in neutral, pronation and supination) (Table 4,5,6)

(2) Pronation - supination (Table 7,8)

(3) Wrist flexion - extension (in pronation and supination) (Table 9,10)

(4) Finger extension - flexion (in neutral) (Table 11)

During these test movements, under low load functional movement conditions, the global stabilizer muscles should demonstrate easy control. If the global stabilizer is inefficient then the global mobilizer synergists are required to take over the low threshold recruitment role, which they are not biomechanically suited for. When this occurs, movements specific to the dominant mobilizer are easily observed. For example, during elbow flexion in neutral (Table 4), if brachialis and brachioradialis are inefficient then extensor carpi radialis longus often takes on the role of low threshold elbow flexion. This is identified by the observation that during low load elbow flexion the wrist extends or radially deviates at the same time. Mobilizer dominance over the stability muscles under low load conditions is considered to be a poor movement strategy or pattern (Janda 1983, Sahrmann 2001, Comerford and Mottram 2001a).

The site and direction of give usually relates to the location of symptoms and the direction or position of symptom provocation. This uncontrolled movement produces direction specific stress and strain on myofascial, articular, neural or connective tissues. For example, with elbow flexion in pronation: site = distal radio-ulnar, carpal joints, direction = extension (Table 5). Once a dysfunctional pattern (give) has been identified during testing the therapist should assess the subjects ability to actively control the give. For example, if a shoulder lateral rotation give is observed during the forearm supination test (Table 8) the therapist

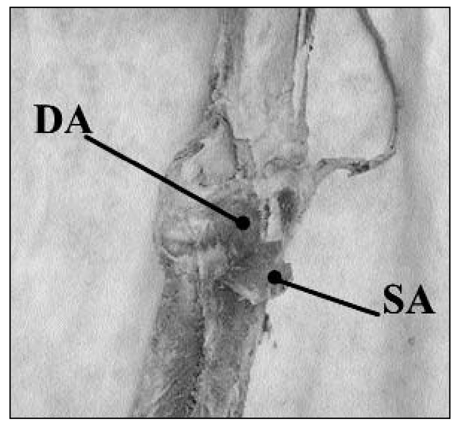

Figure 4. Deep fibres of anconeus (DA) and superficial fibres of anconeus (SA) (reflected back). The deep fibres originate from the lateral epicondyle, the adjacent joint capsule, the annular ligament and the radial collateral ligament. They run medially downward to the supero-lateral aspect of the olecranon and the fascia covering the head of the radius. Ranging from I-3 cm in length, these fibres are not particularly suited to elbow extension and do not have the leverage to produce abduction of the elbow. The superficial fibres originate from the postero-inferior aspect of the lateral epicondyle and run medially and distally in a triangular form to insert on the lateral surface of the olecranon and upper posterior surface of the ulna.

should assess whether the subject can perform forearm supination with control of the give. That is, can the supination test be performed with the forearm rotating around the long axis of the forearm and without shoulder lateral rotation? If the correct pattern of movement is difficult to perform actively then a motor control stability dysfunction is implicated. If active control of the dysfunction is poor, rehabilitation should be directed to low threshold motor control retraining of the uncontrolled movements until a more correct pattern is established (Richardson et al. 1999, Jull 2000, Comerford & Mottram 2001b).

Correction of Movement Dysfunction

Following a detailed assessment of the local and global stability function and identification of the stability dysfunction (in terms of site and direction) a rehabilitation process can be planned. Comerford & Mottram (2001b) suggest the integration of four key principles of stability rehabilitation. These principles of stability rehabilitation are detailed in Table 12.

Principle I: Control of the neutral joint position

Facilitation techniques for low threshold slow motor recruitment of the local stability system are suggested in Tables 13, 14, 15. Two categories are detailed. The first (A) uses very specific unloaded contraction of the local stability muscles; the second (B) uses low functional load or non-neutral

Table 3. Characteristics of muscle dysfunction

LOCAL STABILIZER	GLOBAL STABILIZER	GLOBAL MOBILIZER
• Motor control deficit associated with delayed timing or low threshold recruitment deficiency • Reacts to pain and pathology with altered recruitment • ↓ muscle stiffness and poor segmental control • Loss of low threshold control of joint neutral position	• Muscle active shortening (joint passive (loss of inner range control) • If hypermobile - poor control of excessive range • Poor low threshold tonic recruitment • Poor eccentric control • Poor rotation dissociation	• Loss of myofascial extensibility - limits physiological and/or accessory motion (which must be compensated for elsewhere) • Overactive low threshold, low load recruitment • Reacts to pain and pathology with spasm / overactivity

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Table 4. Diagnosis of movement dysfunction - movement pattern: Elbow flexion ↔ extension in neutral

ELBOW Flexion ***& extension*** forearm neutral		
Test Movement (starting position)	Upper arm and elbow by the side with the elbow flexed 90°, the forearm horizontal and the hand pointing forward with the wrist relaxed and palm facing in.	
Ideal Pattern of Movement	The elbow flexes and extends smoothly with brachialis and brachioradialis dominant. The wrist should be in neutral, without ulnar or radial deviation. There should be no observable wrist or forearm movement	
Site of Give uncontrolled movement	**Direction of Give** fault observed	**Dominant muscle**
• Wrist (distal radio-ulnar-carpal & mid-carpal joints)	**Radial deviation** and wrist extension	**Extensor carpi radialis longus** **Extensor carpi radialis brevis** **Extensor pollicis longus** Extensor pollicis brevis
• Superior radio-ulnar joint	Pronation	Pronator teres **Extensor carpi radialis longus**

Note: The most frequently observed give and the most dominant mobilizer are highlighted in bold

positions to retrain the integrative local and global stability muscle function (Comerford and Mottram 2001b). Once specific retraining and recruitment of the local stability muscles has been achieved, the recruitment pattern can be integrated into functional postures and positions. When the low threshold activation of a local stabilizer is sensed as feeling easy, or low effort, during a ten second sustained contraction, repeated ten times then it can be readily integrated into function.

Principle II: Retrain dynamic control of the direction of the stability dysfunction

This should be retrained concurrently with Principle I. Retraining the control of direction can be achieved with slow, low load movements with fifteen - twenty repetitions. The global stability muscles (with the local stability muscles) maintain continual activation throughout the movement. Stability muscles are retrained to eliminate or control motion at the give while movement occurs elsewhere. The range where motion can be controlled eccentrically as well as concentrically may not be the same. This is observed by a lack of smooth return. There is often a 'jerking' motion and this can be easily monitored by gently palpating (at the proximal joint line) the relevant movement pattern. The joint should only move through the range that is smoothly controlled both concentrically and eccentrically.

Principle III: Rehabilitate global stabilizer control through range

This may commence when there is reasonable control of the direction of give (Principle II). Retraining control through range has three requirements:

i) The global stabilizer concentrically shortens to move the joint towards inner range without substitution by other muscles

ii) The global stabilizer is required to isometrically hold this position for postural alignment and control (suggested 10 seconds hold and 10 repetitions)

iii) The global stabilizer should eccentrically control the return through range against gravity (especially rotation)

The muscle must be able to perform these three requirements demonstrating efficient low threshold recruitment.

Principle IV: Active lengthening or inhibition of the global mobilizers

Active lengthening of the global mobilizer muscles should not begin until there is control of the direction of give and reasonable retraining of the global stabilizers through range

Table 5. Diagnosis of movement dysfunction - movement pattern: Elbow flexion ↔ extension in pronation

ELBOW Flexion ***& extension*** forearm pronated		
Test Movement (starting position)	Upper arm and elbow by the side with the elbow flexed 90°, the forearm horizontal and the hand pointing forward with the wrist relaxed and palm facing down.	
Ideal Pattern of Movement	The elbow flexes and extends smoothly with brachialis and brachioradialis dominant. The wrist should be in neutral, without ulnar or radial deviation. There should be no observable wrist or forearm movement.	
Site of Give uncontrolled movement	**Direction of Give** fault observed	**Dominant muscle**
• Wrist (distal radio-ulnar-carpal & mid-carpal joints)	**Wrist extension** and radial deviation	**Extensor carpi radialis longus** **Extensor carpi radialis brevis** Extensor pollicis longus Extensor pollicis brevis
• Superior radio-ulnar joint	Pronation (excessive)	Pronator teres **Extensor carpi radialis longus**
• Shoulder (scapulo-thoracic & gleno-humeral joints)	Gleno-humeral medial rotation with slight abduction and scapular elevation and tilt	Pectoralis major Levator scapula Pectoralis minor Latissimus dorsi

Note: The most frequently observed give and the most dominant mobilizer are highlighted in bold

control. The therapist should be aware that neural tissue in the forearm may mimic a muscle stretch sensation. Passive mobilisation of myofascial restrictions can begin early in treatment so long as the therapist controls potential compensations or gives. Myofascial trigger point (MTP) release can be a useful tool to regain myofascial extensibility. Inhibitory lengthening techniques are appropriate for regaining extensibility in myofascial structures that are habitually dominant. A useful technique, active inhibitory re-stabilization, has been described (Comerford & Mottram 2001b). The connective tissue elements of myofascial restriction may need to be manually mobilized.

Neurodynamic influences: Local

The nerves of the forearm have significant anatomical relations to various muscles. For example, the median nerve enters the forearm between the heads of pronator teres and is in close proximity to flexor digitorum superficialis, flexor digitorum profundus, and flexor carpi radialis. The ulnar nerve enters the forearm between the two heads of flexor carpi ulnaris and descends on flexor digitorum profundus. At the forearm, the radial nerve divides into superficial and deep branches. The superficial branch is anterior to pronator teres and then it descends deep to brachioradialis and distally to extensor carpi radialis longus. Its deep branch passes between the deep and superficial bands of supinator and continues between the superficial and deep extensor muscles (Williams et al. 1989). Uncontrolled movement may compromise these nerves.

Nerves are exposed to different forces along their course as they make contact with neighbouring bone, muscle and fascia (Butler 2000). Daily movements and many physical activities are likely to induce at least temporary changes in axonal transport (Shacklock 1995). Pressure or irritation of nerves may be increased when neighbouring muscles are passively stretched or when joints are positioned in a way that decreases the available space in the adjacent nerve tunnel. Due to anatomical considerations, interfaces between the peripheral nerves (radial, median and ulnar nerves) and the joints, connective tissues and muscles of the elbow and forearm are obvious sites of neural entrapment, compression or irritation related to stability or mobility dysfunction in this region. Lateral elbow / posterior forearm symptoms

Table 6. Diagnosis of movement dysfunction - movement pattern: Elbow flexion ↔ extension in supination

ELBOW Flexion ***& extension*** forearm supinated		
Test Movement (starting position)	Upper arm and elbow by the side with the elbow flexed 90°, the forearm horizontal and the hand pointing forward, with the wrist relaxed and palm facing up.	
Ideal Pattern of Movement	The elbow flexes and extends smoothly with brachialis and brachioradialis dominant. The wrist should be in neutral, without ulnar or radial deviation. There should be no observable wrist or forearm movement.	
Site of Give uncontrolled movement	**Direction of Give** fault observed	**Dominant muscle**
• Wrist (distal radio-ulnar, carpal & mid-carpal joints)	**Wrist and finger flexion with ulnar deviation**	**Flexor carpi ulnaris** **Flexor digitorum superficialis** Flexor digitorum profundus
	(Wrist extension with ulnar deviation)	Extensor carpi ulnaris (humeral head) Extensor digitorum Extensor digiti minimi
• Shoulder (scapulo-thoracic & gleno-humeral joint)	**Gleno-humeral lateral rotation** and scapular retraction and elevation	**Infraspinatus** **Teres minor** Posterior deltoids Rhomboids
	Gleno-humeral adduction	Latissimus dorsi Pectoralis major

Note: The most frequently observed give and the most dominant mobilizer are highlighted in bold

Table 7. Diagnosis of movement dysfunction - movement pattern: Forearm pronation ↔ supination

FOREARM Pronation ***& supination***		
Test Movement (starting position)	Upper arm and elbow relaxed by the side with the elbow flexed 90°, the forearm horizontal and the hand pointing forward.	
Ideal Pattern of Movement	The forearm pronates and supinates (palm turns up and down) along a longitudinal axis through the forearm and middle finger. The movement should 'pivot' around the middle finger with pronator quadratus and brachioradialis dominant. The wrist should stay relaxed without ulnar or radial deviation. There should be no observable wrist or shoulder movement. (e.g. the elbow should not move away from the body or the wrist towards the body).	
Site of Give uncontrolled movement	**Direction of Give** fault observed	**Dominant muscle**
• Shoulder (scapulo-thoracic & gleno-humeral joint)	**Gleno-humeral medial rotation and abduction** with scapular elevation	Pectoralis major and minor **Anterior deltoid** **Levator scapula** Latissimus dorsi
• Elbow (humero-ulnar & superior radio-ulnar joint)	Pronation and extension	Pronator teres Triceps brachii (long head) Palmaris longus
	Pronation and flexion	Pronator teres Extensor carpi radialis longus Extensor carpi radialis brevis
• Wrist (distal radio-ulnar-carpal & mid-carpal joints)	**Ulnar deviation and flexion**	**Flexor carpi ulnaris** Flexor digitorum superficialis Flexor digitorum profundus Flexor pollicis longus
• Thumb (carpo-metacarpal and 1st metacarpal-phalangeal joints)	Flexion	Flexor pollicis longus

Note: The most frequently observed give and the most dominant mobilizer are highlighted in bold

Table 8. Diagnosis of movement dysfunction - movement pattern: Forearm pronation ↔ supination

FOREARM Pronation ***& supination***		
Test Movement (starting position)	Upper arm and elbow relaxed by the side with the elbow flexed 90°, the forearm horizontal and the hand pointing forward.	
Ideal Pattern of Movement	The forearm supinates and pronates (palm turns up and down) along a longitudinal axis through the forearm and middle finger. The movement should 'pivot' around the middle finger with supinator dominant. The wrist should stay relaxed without ulnar or radial deviation. There should be no observable wrist or shoulder movement (e.g. the elbow should not move towards the body or the wrist away from the body)	
Site of Give uncontrolled movement	**Direction of Give** fault observed	**Dominant muscle**
• Shoulder (scapulo-thoracic & gleno-humeral joint)	**Gleno-humeral lateral rotation** with scapular downward rotation	**Infraspinatus** **Teres minor** Posterior deltoid Rhomboids Pectoralis minor Levator scapula
	Glen-humeral adduction	Latissimus dorsi Pectoralis major
• Elbow (humero-ulnar & superior radio-ulnar joint)	Flexion	Biceps brachii **Extensor carpi radialis longus** **Extensor carpi radialis brevis**
• Wrist (distal radio-ulnar-carpal & mid-carpal joints)	**Radial deviation and extension**	**Extensor carpi radialis longus** **Extensor carpi radialis brevis** Extensor pollicis longus Extensor pollicis brevis
• Thumb (1st metacarpal-phalangeal joint)	Extension	Extensor pollicis longus Extensor pollicis brevis

Note: The most frequently observed give and the most dominant mobilizer are highlighted in bold

Table 9. Diagnosis of movement dysfunction - movement pattern: Wrist extension and flexion in pronation

WRIST Extension ***& flexion*** forearm pronated		
Test Movement (starting position)	Upper arm and elbow relaxed by the side with the elbow flexed 90°, the forearm horizontal with the hand pointing forward and the fingers relaxed and palm facing down.	
Ideal Pattern of Movement	The wrist extends and flexes smoothly with extensor carpi ulnaris dominant. There should be no ulnar or radial deviation. The movement should not demonstrate excessive thumb or finger extension. There should be no observable elbow movement and the fingers and thumb should stay relaxed.	
Site of Give uncontrolled movement	**Direction of Give** fault observed	**Dominant muscle**
• Elbow (humero-ulnar & superior radio-ulnar joint)	**Flexion**	**Extensor carpi radialis longus** **Extensor carpi radialis brevis** Pronator teres Biceps brachii
• Superior radio-ulnar joint	Supination +/- Elbow flexion	**Extensor carpi radialis longus** **Extensor pollicis longus** **Extensor pollicis brevis** Biceps brachii
• Wrist (distal radio-ulnar-carpal & mid-carpal joints)	**Radial deviation**	**Extensor carpi radialis longus** **Extensor carpi radialis brevis** Abductor pollicis longus **Extensor pollicis longus** **Extensor pollicis brevis**
• Fingers	**Extension**	**Extensor digitorum** Extensor indicis
• Thumb (carpo-metacarpal and 1st metacarpal-phalangeal joints)	**Extension**	**Extensor pollicis longus** **Extensor pollicis brevis**

Note: The most frequently observed give and the most dominant mobilizer are highlighted in bold

may result from compression or irritation of the radial nerve (Grant et al, 1995). Similarly, medial elbow / forearm symptoms are commonly related to the ulnar nerve. Anterior forearm symptoms are commonly due to compromise of the median nerve. The median nerve may also be involved in medial or lateral forearm symptoms. Even though these patterns may exist, it should be noted that all upper limb neurodynamic tension tests (ULNT) should be assessed (Butler, 2000). Some mechanisms of neural irritation are discussed below.

The flexor carpi ulnaris muscle could influence the ulnar nerve when the fingers are flexed because the nerve passes under the muscle (Shacklock 1995). This may be increased when ulnar deviation is combined with finger or wrist flexion. The ulnar nerve can also be strained with valgus stress on the elbow and neural tension can increase with traction of the humero-ulnar joint. This can occur during throwing or racquet sports. The median nerve passes through the heads of pronator teres and can be compressed with pronation and wrist flexion at the carpal tunnel. The median nerve has shown elevated vibration thresholds in its distribution, and reduced transverse movement at the carpal tunnel, in patients who present with repetitive strain injury of the forearm / hand related repetitive work with the hands (Greening et al. 1998, 2000). Compression of the radial head on the convexity of the capitellum secondary to valgus elbow stress is seen as an overuse or overload phenomenon in pitchers (Andrews & Whiteside 1993). The radial nerve (posterior interosseous) may be compromised by supinator tightening over the nerve in pronation and by the extensor carpi radialis brevis tightening in wrist and finger flexion (Sunderland 1978). These examples are illustrated in Table 16.

Neurodynamic and vascular influences: Remote ('Thoracic Outlet')

There are many proximal sites where the neuro-vascular structures supplying the arm can be

Table 10. Diagnosis of movement dysfunction - movement pattern: Wrist flexion and extension in supination

WRIST Flexion ***& Extension*** forearm supinated		
Test Movement (starting position)	Upper arm and elbow relaxed by the side with the elbow flexed 90°, the forearm horizontal with the hand pointing forward and the fingers relaxed and palm facing up.	
Ideal Pattern of Movement	The wrist flexes and extends smoothly with flexor carpi ulnaris (ulnar head) and abductor pollicis longus dominant. There should be no ulnar or radial deviation. The movement should not demonstrate excessive finger flexion. There should be no observable elbow movement and the fingers should stay relaxed.	
Site of Give uncontrolled movement	**Direction of Give** fault observed	**Dominant muscle**
• Elbow (humero-ulnar & superior radio-ulnar joint)	**Flexion**	**Flexor carpi radialis** Biceps brachii
• Superior radio-ulnar joint	Pronation	Pronator teres Flexor carpi radialis Palmaris longus
• Wrist (distal radio-ulnar-carpal & mid-carpal joints)	**Ulnar deviation**	Flexor carpi ulnaris (humeral head)
• Fingers	Flexion	**Flexor digitorum superficialis** **Flexor digitorum profundus** Flexor pollicis longus

Note: The most frequently observed give and the most dominant mobilizer are highlighted in bold

compromised (thoracic outlet syndrome) with three (3) sites identified by most authors as being significant sites of compression (McClune et al 1998, Halle 1996). These are:

(i) the interscalene triangle (anterior scalene, middle scalene and 1st rib),
(ii) the costo-clavicular space (clavicle and 1st rib)
(iii) the pectoral thoracic space (pectoralis minor, coracoid process and ribcage). Neural compression of the thoracic outlet is characterised by referred pain and paraesthesia primarily in the ulnar nerve distribution with some median nerve involvement and motor changes to the finger flexors and the intrinsic muscles of the hand (Halle 1996). This referred pain or paraesthesia is commonly reported as elbow or forearm symptoms. Elvey (1995) feels that muscles act to protect nerves. This means that muscles may respond to a lack of neural mobility with protec-tive responses (restri-ction) or inhibition (give). Motor changes, which result from thoracic outlet disorders, are contributing factors to the development of regional muscle imbalance and sub-sequent mechanical stress and strain at the elbow and forearm.

Several specific muscle dys-functions can be related to thoracic outlet compression (McClune et al. 1998):

1. 'Short' or overactive anterior or middle scalene muscles directly compressing the neural plexus at the interscalene triangle.
2. Elevated 1^{st} rib compressing the costo-clavicular space (secondary to short scalenae).
3. Scapular depression or downward rotation compressing

Table 11. Diagnosis of movement dysfunction - movement pattern: finger extension ↔ flexion

FINGER Extension ***& flexion*** forearm neutral with a loose fist		
Test Movement (starting position)	Upper arm and elbow relaxed by the side with the elbow flexed 90°, the forearm horizontal with the hand pointing forward and the palm facing in	
Ideal Pattern of Movement	The fingers extend and flex smoothly with extensor carpi ulnaris (ulnar head) controlling the wrist in neutral extension-flexion. There should be no ulnar or radial deviation. The movement should not demonstrate excessive wrist flexion or metacarpo- phalangeal hyperextension. There should be no observable elbow movement.	
Site of Give uncontrolled movement	**Direction of Give** fault observed	**Dominant muscle**
• Wrist (distal radio-ulnar-carpal & mid-carpal joints)	**Flexion**	**Flexor carpi ulnaris (humeral head)** Flexor digitorum superficialis **Flexor digitorum profundus** Flexor pollicis longus
	Ulnar deviation	**Flexor carpi ulnaris (humeral head)** **Extensor digitorum** Extensor digiti minimi
• Fingers (metacarpo-phalangeal joint)	**Hyper-extension**	**Extensor digitorum**

Note: The most frequently observed give and the most dominant mobilizer are highlighted in bold

the costo-clavicular space (secondary to a loss of scapular control associated with inefficient serratus anterior and trapezius muscles).

4. Short or overactive pectoralis minor directly compressing the costo-clavicular space.

Proximal control related to movement dysfunction of the elbow and forearm

The cervical spine, scapulo-thoracic and gleno-humeral joints and related neural and myofascial structures may influence movement dysfunction and symptoms at the elbow and forearm. Proximal movement dysfunction needs to be assessed and rehabilitated if a relationship link to elbow and forearm problems can be identified (Mottram 1997, Comerford & Mottram 2001b). There are many ways that proximal dysfunction can influence elbow and forearm symptoms or function.

Cervical articular dysfunction and related neural irritation or compression commonly can contribute to radicular symptoms in the elbow and forearm (Maitland 1986, Cyriax 1996, Petty & Moore 2001,). The dermatomes of C5 to T1 can affect elbow and forearm symptoms. The muscles that control elbow and forearm motion are innervated by the musculo-cutaneous, radial, median and ulnar nerves and have spinal level segmental innervation from C6 to T1. Consequently, spinal or other related tissues, which may irritate these structures, can affect both motor function and symptoms at the elbow

Table 12. Principles of stability rehabilitation

I	**Control of the neutral joint position** • Local stabilizer dominant recruitment in mid range positions	Retrain tonic, low threshold activation of the local stability system to increase muscle stiffness and train the functional low load integration of the local and global stabilizer muscles to control the neutral joint position.
II	**Retrain dynamic control of the direction of the stability dysfunction** • Control the give with the global stabilizers (+ local stabilizers) and move in the direction of the 'give' • Rotation has priority	Control the give and move the restriction. Retrain control of the stability dysfunction in the direction of symptom producing movements. Use the low load integration of local and global stabilizer recruitment to control and limit motion at the segment or region of give and then actively move the adjacent restriction. Only move through as much range as the restriction allows or as far as the give is dynamically controlled.
III	**Rehabilitate global stabilizer control through range** • Concentric shortening through inner range • Isometric hold at that position • Eccentric control of return against gravity	Rehabilitate the global stability system to actively control the full available range of joint motion. These muscles are required to be able to actively shorten and control limb load through to the full passive inner range of joint motion. They must also be able to control any hypermobile range. The ability to control rotational forces is an especially important role of the global stabilizers. Eccentric control is important for stability function. This is optimised by low effort, sustained holds in the muscle's shortened position with controlled eccentric lowering.
IV	**Actively regain extensibility of the global mobilizers** • Actively lengthen through full range • Inhibit dominance	When the 2 joint global mobility muscles demonstrate a lack of extensibility (due to overuse or adaptive shortening), then compensatory give occurs elsewhere to maintain function. It becomes necessary to regain extensibility and/or inhibit over-activity.

and forearm. This spinal irritation may be secondary to dysfunction of the cervical muscle control systems. For example, dominant or overactive scalene muscles contribute to excessive flexion loading of the low cervical spine. The relationship between Deep Neck Flexor muscle (DNF) stability function and a modified ULNT can also link cervical dysfunction and neural irritation with secondary elbow and forearm dysfunction. DNF stability function can be measured by the ability to control graduated pressure increases on a Pressure Biofeedback Unit (PBU) placed in the cervical lordosis without excessive recruitment of the superficial global neck flexor muscles as described by Jull (2000). The DNF stability function is assessed with the client's arm in 90° abduction with the elbow and wrist relaxed. The elbow and wrist are then slowly extended to increase tension in neural structures, and the DNF stability function is reassessed. If the DNF stability function is decreased with the ULNT, it links cervical or neural dysfunction with the forearm dysfunction.

Shoulder dysfunction can directly affect neck stability mechanisms. It is possible to combine existing tests to help in assessing treatment priorities or tissue involvement. The Kinetic Medial Rotation Test (KMRT) was described by Sahrmann (1992) and developed further by Comerford (1994). Morrissey (1998) has since validated this test using 3-dimensional movement analysis. The client lies supine with the shoulder abducted to 90° in the plane of the scapula and the hand pointing to the ceiling. The therapist palpates the coracoid and the humeral head to monitor for inferior or anterior movement. The client actively medially rotates the gleno-humeral joint and should ideally be able to achieve 70° of medial rotation without loss of scapular or gleno-humeral stability. Humeral head movement before 70° implicates a primary stability dysfunction of the gleno-humeral joint, while early coracoid movement implicates a primary stability dysfunction of the scapula (impingement). DNF stability function is assessed with the arm in the starting position for the KMRT. The subject performs the KMRT and stops at the point of either coracoid or humeral head inferior-anterior movement. The DNF stability function is then reassessed in this position. A decrease in DNF stability function implicates scapulo-thoracic or gleno-humeral dysfunction coupled with cervical dysfunction. Concurrent cervical and shoulder girdle stability retraining is recommended.

Poor scapular control can also affect cervical movement function. Asymmetrical myofascial tension between the lateral cervical spine and the scapula and ribcage can affect cervical range of rotation and sidebending motion. Increased myofascial tension on the neck can be due to muscle overactivity and shortening or due to passive tension created by a dropped or downwardly rotated scapula 'hanging' off the neck. Either way, this tension will limit ipsilateral rotation or contra-lateral side bending (Comerford 2000). The scapula can compensate for a restriction of gleno-humeral medial rotation by orientating the glenoid more anteriorly and inferiorly (Comerford 1994). This change in scapular position also contributes to asymmetrical myofascial cervical

Table 13. Principle I. ANCONEUS control of joint neutral

	A. Unloaded Facilitation	**Procedure**
Anconeus	Visualization and explanation of the correct activation with tactile feedback	Starting position: elbow flexed to 90° (midway between pronation and supination). Anconeus can be palpated at the posterior and inferior aspect of the lateral epicondyle just inferior to triceps. Activation of the muscle will cause a palpable 'swelling' contraction
	B. Movement & Functional Load Facilitation	**Procedure**
	Resisted extension	Low effort resisted extension in pronation (or supination) will create an effective contraction of anconeus.
	Eccentric elbow flexion	During deceleration of elbow flexion, anconeus will activate. While flexing the elbow, stop mid range, then maintain tension in anconeus.

tension (above). These same issues may also affect the neural system at the thoracic outlet.

Proximal cervical and scapular dysfunction may produce secondary elbow and forearm dysfunction. For example, a gross loss of eccentric control during testing of forearm movements or an inability to progress with the eccentric component of forearm exercises may be due to a loss of scapular stability. This may be observed by a significant improvement of eccentric control when the elbow and shoulder girdle are supported. Regaining extensibility of the short muscles (usually levator scapula, anterior scalene, pectoralis minor, teres minor and infraspinatus) or restabilizing the neck, scapula and shoulder (retrain trapezius, serratus anterior, subscapularis and the deep neck flexors) becomes a rehab priority.

Myofascial trigger point influence

Active myofascial trigger points are well documented as sources of both local and referred pain (Travell & Simons 1999). Movement dysfunction may be the 'trigger' mechanism related to the activation of myofascial trigger points. Active trigger points commonly develop in mobilizer muscles due to over activity. Stabilizer muscles often develop trigger points due to their failure to adequately control movement which results in myofascial strain. These muscle imbalances may result in metabolic stress of myofascial tissue (see Mense and Simons, 2001). Rehabilitation is directed towards regaining the balance in these muscles during dynamic movements. Active myofascial trigger points within the muscles of the elbow and forearm are a significant (though often overlooked) source of elbow and forearm pain. Active myofascial trigger points can refer pain distally in similar (though different) distributions as dermatomes and sclerotomes. Many proximal cervical and shoulder girdle muscles develop active trigger points in the presence of neck or shoulder dysfunction. Many of these trigger points can refer pain distally to the elbow and forearm. Table 17 details local and remote myofascial trigger points that can contribute to elbow and forearm pain.

Summary

Movement dysfunction is frequently related to pain and pathology at the elbow and forearm. This paper attempts to highlight the identification and rehabilitation of stability dysfunction related the elbow and forearm. These clinical findings need to be validated with objective measures and more research is needed in the area.

Table 14. Principle I. SUPINATOR control of joint neutral

	A. Unloaded Facilitation	**Procedure**
Supinator	Visualization and explanation of the correct activation	Starting position: elbow flexed to 90° (midway between pronation and supination). Activation of the deep radial and deep ulnar fibres of Supinator will draw the radius towards the ulna and draw the radius towards the humerus. This should be a low effort contraction. This can be monitored by palpation at the radio-humeral joint line.
	Caudad movement of the radius	Manually palpate and distract the radius caudad. The radius can be actively pulled back (cephalad) by low effort activation of the deep radial and deep ulnar fibres of Supinator.
	B. Movement & Functional Load Facilitation	**Procedure**
	Resist supination	Low effort resistance to supination. Ensure the elbow stays in neutral.
	Deviation (radial → ulnar)	During ulnar deviation the radius moves caudad and it moves cephalad during radial deviation. Start in radial deviation and use active ulnar deviation to facilitate the deep radial and deep ulnar fibres of Supinator.

Table 15. Principle I. PRONATOR QUADRATUS control of joint neutral

	A. Unloaded Facilitation	Procedure
Pronator Quadratus	Visualization and explanation of the correct activation	Starting position: elbow flexed to 90° (midway between pronation and supination). Activation of the muscle will approximate the joint surfaces. This should be a low effort contraction. Monitor this by palpating the distal end of the radius through its anterior aspect. With a correct contraction, the radius and ulna will approximate each other. There should not be overactivity of the long finger flexors or wrist flexors. The client should be able to move the digits or wrist while maintaining this contraction.
	Distraction of the distal radio-ulnar joint	Manually distract the distal radio-ulnar joint (thumb on anterior aspect of the radius and index or 3rd digit on posterior aspect of the ulnar) and actively pull joint back using the deep fibres of Pronator Quadratus.
	B. Movement & Functional Load Facilitation	**Procedure**
	Resist pronation	Low effort isometric resistance to pronation. Ensure the wrist stays in neutral.
	Power grip	Grip a ball or towel with all fingers with low effort with the wrist in neutral pronation-supination. The palmar fascia is continuous with Pronator Quadratus and will be reciprocally tensioned. Monitor this by palpation of the posterior aspect of the ulnar to feel the ulnar move towards the radius.

Table 16. Neurodynamic Influences: Local

Direction of give 'uncontrolled movement'	Dominant Muscle	Neural tissue at risk
Elbow flexion	Extensor Carpi Radialis Longus	Radial nerve
Pronation	Pronator Teres	Radial nerve Median nerve
Wrist extension and radial deviation	Extensor Carpi Radialis Longus	Radial nerve
Wrist flexion and deviation	Flexor Carpi Ulnaris Flexor Carpi Radialis Extensor Carpi Radialis Longus	Median nerve Median nerve Radial nerve
Wrist radial and ulnar deviation	Flexor Carpi Ulnaris Flexor Carpi Radialis	Median nerve Median nerve
Wrist flexion	Finger flexors	Median nerve Ulnar nerve
Wrist extensors	Finger extensors	Radial nerve

Note: the ulnar nerve may be compromised by excessive give into ulnar deviation due to overactivity of flexor carpi ulnaris (humeral head) or extensor carpi ulnaris (humeral head) due to the dysfunctional movement pattern, not to an anatomical relationship of the ulnar nerve to these muscles.

Table 17. Myofascial trigger points related to elbow and forearm pain

	Mobilizers	Stabilizers
Local	Biceps brachii **Triceps brachii** **Extensor carpi radialis longus** **Extensor carpi radialis brevis** Extensor digitorum **Extensor digiti minimi** **Extensor carpi ulnaris** Extensor indicis Extensor pollicis brevis Extensor pollicis longus **Pronator teres** **Palmaris longus** Flexor digitorum superficialis Flexor digitorum profundus Flexor carpi radialis Flexor carpi ulnaris Flexor pollicis longus	Brachialis Anconeus **Brachioradialis** **Supinator** **Extensor carpi ulnaris** Pronator quadratus Abductor pollicis longus
Remote	Scalenae Pectoralis minor Pectoralis major Serratus posterior superior Infraspinatus Latissimus dorsi	**Subclavius** Serratus anterior Supraspinatus **Subscapularis** Teres major Coracobrachialis

Note: Muscles highlighted in bold appear to contribute more significantly to elbow and forearm pain

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