Assessment and rehabilitation of the stability function of psoas major

Sean GT Gibbons BSc (Hons) PT, MSc, MCPA
SMARTERehab
Clinical Leader Stability Physiotherapy
Professional Associate
School of Human Kinetics and Recreation
Memorial University of Newfoundland
144 Gower Street
St. John's, Newfoundland
Canada, A1C 1P3
Tel: 709 689 3303
stabilityphysio@gmail.com

Introduction

Psoas major is the largest muscle in cross section at the lower levels of the lumbar spine (McGill et al, 1988) and has the ideal anatomy and position to provide stability (Gracovetsky et al 1981, Nachemson 1968). Despite this, considerable debate exists whether psoas major is important for spinal stability (McGill 2002, Richardson et al 2004). The reasons for this include: the anatomy of psoas major is complex and its deep location makes investigation difficult; previous studies have interpreted psoas major and iliacus as having the same function; recent advances in the understanding of muscle function highlight weaknesses in previous studies; and the traditional interpretation of psoas major role is still popular to clinicians and researchers.

The role of muscles in providing stability has grown considerably over the last two decades.

The concept of stability in itself is not agreed upon and different approaches to rehabilitation have evolved (Comerford and Mottram 2001, McGill 2002, Richardson et al 2004, Sahrmann 2002). Part of the reason for the controversy may be due to the variable requirements of muscles in maintaining stability during multiple human functions. Muscles may have a primary role in providing stability or may have multiple roles in movement and stability. Other considerations are the requirements of muscles under normal low load daily tasks versus activities which require higher loads such as heavy manual handling and impact sports.

The purpose of this paper is detail the clinical assessment and rehabilitation strategies for the stability function of psoas major. The evidence of the function of psoas major will also be briefly reviewed. A better understanding of the implications of the function of psoas major on the stability of the lumbo-pelvic region may improve clinical management of related dysfunction.

Muscle Function

Information regarding muscle function may be obtained from four key sources (Gibbons 2005). These are listed in table 1. Each aspect can be individually assessed using the available literature to understand the functional potential a muscle has. This can then be used to functionally classify the muscle.

Table 1: Sources of information for understanding muscle function in order to functionally classify muscles (reproduced with permission from Kinetic Control)

Function	Dysfunction
Anatomical location & structure Biomechanical potential Neurophysiology	Consistent & characteristic changes in the presence of pain or pathology

Muscle Classification

Comerford and Mottram (2001) presented a new model of muscle classification. This divides muscles into local stabilizers, global stabilizers and global mobilizers (table 2). It is

very simplistic to place a muscle in one category, however this should be considered a model of best function where a muscle may have more than one dominant function and thus may be categorized under two or even three headings. On the other hand, a muscle may have multiple functions, but one is very minor. Here, the muscle would be categorized under its primary function. A summary of the functional classification of psoas major is provided below in table 3.

Anatomy & Physiology

Psoas major has muscular attachments (individual fascicles) to the anterior aspect of all lumbar transverse processes and to the antero-medial aspect of all the lumbar discs and adjoining bodies with the exception of the L5-S1 disc (Bogduk et al 1992, Gibbons 2004). These have been termed 'anterior' and 'posterior', respectively for their relative position on the spine.

Psoas major is a unipennate muscle with a pennation of approximately 45° - 75°. This means that the fiber length does not extend the full length of the muscle, but runs medial to lateral and ranges from 3 – 8cm. The individual fascicles run infero-laterally to reach a central tendon where they descend over the pelvic brim and share a common insertion with iliacus to the lesser trochanter.

Psoas major also has considerable fascial relations. The superior psoas major fascia continues to form the medial arcuate ligament and links psoas major to the diaphragm. As psoas major descends towards the pelvic brim, its fascia descends infero-medially and is continuous with the pelvic floor fascia. The transversalis fascia is the internal fascia covering transversus abdominus. Below the iliac crest this fascia is continuous with the psoas major fascia, hence links transversus abdominus and psoas major. Psoas major does not simply pass over the pelvic brim like a pulley. As it crosses the iliopectineal eminence, it has a strong attachment to the pelvis. This may constitute an innominate ligament (Gibbons 2004).

The anterior and posterior fascicles of psoas major have a separate nerve supply. The posterior fascicles are supplied by the ventral rami of spinal nerves T12 through L4. The anterior fascicles are supplied by branches of the femoral nerve from L2, 3 and 4 (Gibbons 1999, 2004). The anterior and posterior fascicles of psoas major is comparable to the deep and superficial fibers of lumbar multifidus, which have been shown to have separate functional roles in spinal stability (Moseley et al 2002).

Biomechanics

The biomechanics of psoas major suggest that it has minimal capability to produce movement at the lumbar spine (Bogduk et al 1992, Gibbons 2004, Rab et al 1977, Santaguida and McGill 1995). The primary force is axial compression which may create segmental stiffness (Janevic et al 1991) and resist shear (McGill 2002). Psoas major crosses the sacroiliac joint hence must create a force there. Although psoas major is generally thought to anteriorly rotate the innominate (Bachrach et al 1991, Snijders et al 1995), a newer model suggests that psoas major has the potential to posteriorly rotate the innominate in the erect posture (Gibbons et al 2001). As well, from an anatomical standpoint, it is also in an ideal position to resist translation at the long and short arm of the sacroiliac joint. At the hip, Yoshio et al (2002) concluded that the psoas major contributed very little to hip flexion and its primary role was for hip stability. This was accomplished through axial shortening which maintained the femoral head in the acetabulum. They found that increased lumbar stability was achieved through greater angles of hip flexion.

Neurophysiology

Numerous studies have assessed psoas major with electromyography (EMG), however very little information can be taken from them. This is because psoas major cannot be investigated with superficial EMG and EMG from iliacus

Table 2: Function and characteristics of local stabiliser, global stabiliser and global mobiliser muscles in normal function and after the presence of pain (dysfunction) (Review: Comerford & Mottram, 2001)

LOCAL STABILISER MUSCLE ROLE	GLOBAL STABILISER MUSCLE ROLE	GLOBAL MOBILISER MUSCLE ROLE
Function & Characteristics: • ↑ muscle stiffness to control segmental motion • Controls the <u>neutral</u> 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 muscle stiffness prior to motion stress • +/- Muscle activity is independent of direction of movement • +/- Continuous activity throughout movement • Proprioceptive input re: joint position, range and rate of movement	**_Function & Characteristics:_** • Generates force to <u>control</u> <u>range</u> of motion • Contraction = <u>eccentric</u> length change ∴ control throughout range • Functional ability to: (i) shorten through the full inner range of joint motion (ii) isometrically hold position (iii) eccentrically control the return against gravity and control hyper-mobile outer range of joint motion if present • Deceleration of low load/force momentum (especially axial plane: rotation) • Non-continuous activity • Muscle activity is direction dependent ∴ powerfully influenced by muscles with antagonistic actions	**_Function & Characteristics:_** • Generates torque to <u>produce</u> <u>range</u> of joint movement • Contraction = <u>concentric</u> length change ∴ concentric production of movement (rather than eccentric control) • Concentric acceleration of movement (especially sagittal plane: flexion / extension) • Shock absorption of high load • Muscle activity is very direction dependent • Intermittent muscle activity (very on : off phasic patterns of activity – often brief bursts of activity to accelerate the motion segment then momentum maintains movement)
Dysfunction: • Motor control deficit associated with delayed timing or recruitment deficiency • Reacts to pain and pathology with inhibition • ↓ muscle stiffness and poor segmental control • Loss of control of joint neutral position	**_Dysfunction:_** • Muscle lacks the ability to (i) shorten through the full inner range of joint motion (ii) isometrically hold position (iii) eccentrically control the return • If hypermobile - poor control of excessive range • Poor low threshold tonic recruitment • Poor rotation dissociation • Inhibition by dominant antagonists	**_Dysfunction:_** • Myo-fascial shortening – 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

Table 3: Summary of the evidence for the functional classification of psoas major

Function	
Anatomy	
Local stabilizer	• Segmental attachment
Biomechanics	
Local stabilizer	• Minimal movement production (hip and lumbar spine) • Can resist translation (hip and lumbar spine)
Global stabilizer	• Produces a lumbar lordosis
Neurophysiology	
Global stabilizer	• Eccentric control of spinal movement • Controls lumbar lordosis
Dysfunction	
Changes in the presence of pain & pathology	
Local stabilizer	• Altered low threshold recruitment • Segmental atrophy

cannot be considered the same as that from psoas major. As well, there are normalization issues and simplistic methodologies have been used which have not been useful to ascertain the complex function of psoas major.

It does appear that psoas major contributes to hip flexion, but is not the primary hip flexor. Iliacus is more active than psoas major during hip flexion (Andersson et al 1995). The methodology used could not provide information if the EMG activity was present to stabilize the spine, pelvis, hip, produce hip flexion or all of these together. It should be appreciated that rectus femoris, tensor fascia latae and sartorius are more efficient hip flexors than ilacus (Dostal et al 1986). Psoas major is minimally involved in producing lumbar spine movement (Andersson et al 1995, Juker et al 1998), but it may contribute to producing the lumbar lordosis (Andersson et al 1995) and eccentric control of side flexion (Andersson et al 1995, 1997). The above investigations appeared to record EMG from the anterior fasciculi, hence the functions noted above should be considered from anterior psoas major, not posterior psoas major.

Consistent Changes in the presence of Pain and Pathology

Within the classification in table 2, local stability muscles exhibit consistent and characteristic changes following a significant episode of pain (Comerford and Mottram 2001). The relevant characteristics for psoas major include segmental atrophy and altered patterns of low threshold recruitment.

Dangaria and Naesh (1998) assessed the cross sectional area of psoas major in unilateral sciatica caused by disc herniation. There was significant reduction in the CSA of psoas major at the level and the site of disc herniation on the ipsilateral side. More recently, Barker et al (2004) found segmental atrophy in psoas major and lumbar multifidus in subjects with unilateral low back pain (LBP). These are similar patterns of atrophy previously observed

in lumbar multifidus following acute and sub acute low back pain (Hides et al, 1994).

The anatomical location of psoas major makes direct methods of measurement difficult therefore an indirect method was utilized. Indirect methods have been previously used during specific exercises by Jull (2000) and O'Sullivan et al (1997). A specific motor control exercise for psoas major was developed (Gibbons et al 2002) and is described in detail below. Briefly, this involves a hip shortening exercise with minimal activity in the superficial muscles.

Male subjects with a history of low back pain (but currently pain free) or with no history of low back pain were recruited. Superficial EMG was recorded from multi-joint hip muscles that could potentially contribute to the movement during the exercise. Psoas major was measured via ultrasound imaging at the point it crosses the pelvic brim and the lumbar spine neutral position was monitored with a pressure biofeedback. It was hypothesized that the subjects with a history of low back pain would have greater amounts of superficial EMG activity during the exercise than the subjects with no history of low back pain. The results showed that the subjects with a history of low back pain had higher amounts of superficial EMG during the exercise and lost the neutral spine position more often and to a greater extent than subjects with no history of low back pain. One of the reasons for this result may be due to a reduced function of psoas major to produce the hip shortening movement in the subjects with a history of low back pain (Gibbons et al, 2007).

Model of Psoas Major Function

The functional muscle classification of psoas major is summarized below in table 3. The current evidence suggests psoas major is an important stabilizer of the lumbo-pelvic region. A common model of lumbar stability shows the musculature forming a cylinder. The top of the cylinder is the diaphragm, the bottom is the

pelvic floor and the wall is formed by the segmentally attaching abdominal and posterior spinal musculature, specifically transversus abdominus and the segmental fibers of lumbar multifidus (Bartlink 1957, Morris 1961, Richardson et al 1999).

There is considerable evidence to support that this system works together, rather than as isolated components (Hodges et al 2003, Hodges et al 1997, Moseley et al 2002, Richardson et al 2002, Sapsford et al 2001, Shirley et al 2003). Psoas major has intimate anatomical attachments to the diaphragm and the pelvic floor. This unique anatomical disposition allows psoas major to act as a link between the diaphragm and the pelvic floor that may help maintain stability of the lumbar cylinder mechanism. The role of psoas major may be conceptually visualized as a rod in the middle of a cylinder, however this mechanism needs to be assessed with in vivo studies.

Psoas major should be regarded as an ingenious anatomical design. A mechanism to simultaneously flex the hip and maintain lumbo-pelvic stability is needed for normal function. Psoas major has the ability to control the lumbar lordosis, pelvic tilt, lumbar and SIJ translation, and rotation of the innominates, while controlling hip translation and *contributing* to hip flexion. When the demands of the hip are increased, the mechanism will automatically augment stability in the lumbo-pelvic region. Retraining should consider all these functional requirements.

Specific motor control stability exercise for psoas major
Specific motor control stability exercise (sometimes called motor control exercise or specific spinal stabilization exercise) is now a widely used form of exercise and there is an extensive body of literature that provides a rationale for the mechanism of action (Maher et al 2005). In the spine, these exercises involve specific recruitment biased towards deep muscles while reducing unwanted over activity

of other muscles (Ferreira et al 2006). This exercise approach may be superficial in other areas of the body (i.e. scapula). Exercises have been developed for transversus abdominis, the deep segmental fibres of lumbar multifidus (Richardson et al 2004), and the deep neck flexors (Jull et al 2002). There is a growing body of evidence for the efficacy of such exercises (Ferreira et al 2006). A recent report shows that a specific motor control stability exercise for psoas major may provide temporary pain control in subjects with acute pain (Gibbons 2007).

The specific motor control stability exercise for psoas major involves axial shortening with facilitation through the hip. This *local muscle* role of psoas major is to produce axial compression along its line of pull. This has the effect of compressing the vertebral bodies while longitudinally pulling the head of the femur into the acetabulum. With efficient recruitment, psoas major has the ability to resist translation in the lumbar spine, SIJ and hip. This 'pulling in the hip' or 'shortening the leg' action should be localized to the hip joint. There should not be any lateral tilt ('hitching'), anterior or posterior tilt, or rotation of the pelvis. Likewise, any spinal rotation, flexion or extension should be discouraged and there should also be normal breathing.

Assessment and Rehabilitation
The assessment and retraining of the stability role of psoas major is outlined in figure 1.

Stage 1a: Instruction for the specific action of psoas major - axial shortening
The first stage must be viewed as only instruction in the specific longitudinal shortening action of psoas major. This is so the subject understands and is aware of the contraction required. It is not part of the segmental assessment or rehabilitation, although information regarding sensation of effort, proprioception and substitution strategies is gained. Psoas should have the ability to activate in any position of the trunk and under

any load situation, however supine lying (and sometimes inclined sitting) is usually the best position to instruct in. The contralateral knee may be flexed for comfort if required.

Monitoring technique
When the assessment is performed in supine or inclined sitting, it is possible for the therapist to monitor the exercise with a simple palpation technique. The therapist uses the second and third digits ('peace sign') to palpate the anterior superior iliac spine (ASIS) and the soft tissue below in the antero-lateral groin (approximately 5cm below the ASIS) (figure 2). The upper finger assesses for control of movement of the pelvis and maintenance of the lumbo-pelvic neutral position while the lower finger checks for excessive activity in rectus femoris and sartorius. The other hand can be used to monitor the quadriceps for excessive activity and the femoral condyles for femoral shortening. As the client attempts to activate psoas, there should be no movement of the pelvis (assessed by monitoring the ASIS). Any pelvic movement is discouraged. This is considered a loss of the neutral lumbo-pelvic position and is thought to be associated with excessive activity of quadratus lumborum or iliocostalis.

It is important that the client is aware of the sensation of shortening the leg. The therapist should not palpate radial expansion of sartorius or rectus femoris under the lower finger. It is possible for sartorius and the tensor fascia latae (TFL)/ ilio tibial band (ITB) to co – contract to produce shortening of the hip. This would be associated with noticeable muscle contraction and significant resistance to passive rotation of the femur. Rectus femoris and the hamstrings may also co – contract to shorten the hip. This would be associated with noticeable contraction and significant resistance to passive movement of the pelvis.

Step 1
Describe the position of psoas major on the lumbar spine and hip to the subject. The action is vertical shortening so that the hip moves closer to the spine or it 'shortens the hip into the acetabulum'. When in the starting position, it may be useful to passively distract the femur and push it into the acetabulum several times to give the sensation of the action required.

Figure 1: Summary of the stages of psoas major stability rehabilitation
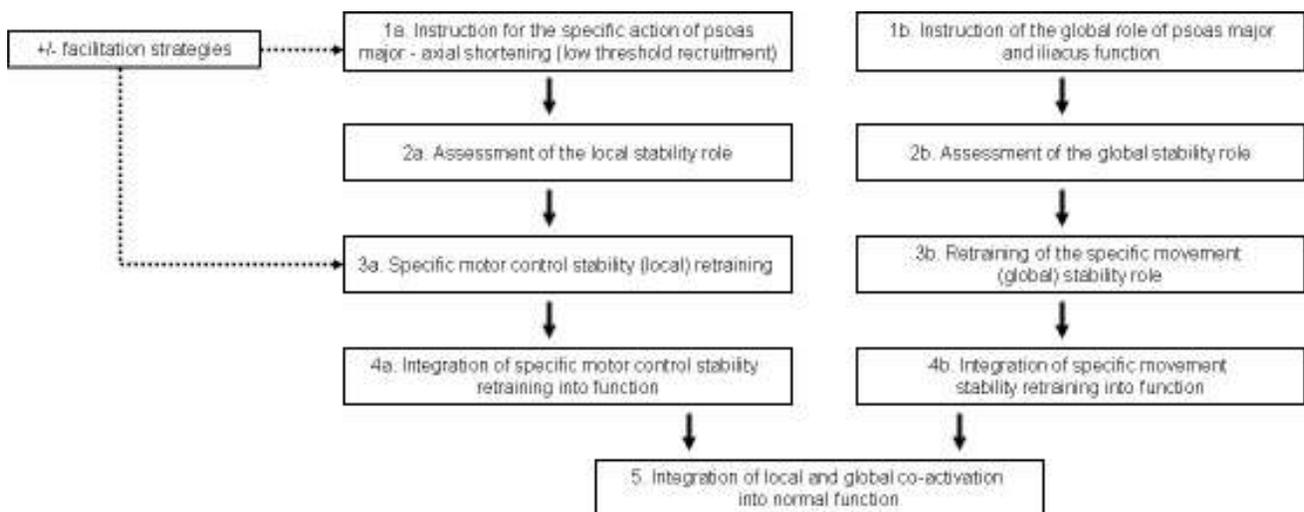
Figure 2: The monitoring technique for the therapist while teaching the psoas major exercise. The therapist monitors the ASIS, the soft tissue below in the antero-lateral groin (approximately 5cm below the ASIS), the quadriceps and the femoral condyles.

Step 2

Starting position: Supine with the lumbar spine in a neutral position. A common substitution strategy is to hitch the hip using quadratus lumborum or iliocostalis. In this situation, long sitting would be preferred instead of supine. The hip should be in neutral rotation (a guide is to position the toes vertically). If the hip is externally rotated at rest, it should be placed in its mid position and actively controlled there.

Step 3

Gently distract the femur and then give an appropriate instruction. Visual, auditory and kinaesthetic learning styles can be implemented to teach people specific motor control stability exercises. There are a variety of strategies to use. The most common are listed in table 4 along with the facilitation strategies. Maintain the distraction during the activation to provide a sensory or afferent stimulus for the longitudinal action of psoas major.

To attempt the segmental stability assessment the client must be able to perform the exercise in supine and sustain a contraction for ten seconds. The criteria for the correct performance of the exercise are outlined in table 5. Table 6 lists the common reasons why clients may not be able to perform the exercise and table 7 outlines the common substitution

strategies and problem solving strategies. As with other local stability muscle exercises, facilitation strategies may be required to work towards the desired specific action of the muscle. The facilitation strategies for psoas major are listed below.

Facilitation Strategies

1. Active hip external rotation

This should be a slow, low effort, small range movement. When the client's hip is normally positioned in external rotation, it is useful to apply a small amount of resistance to external rotation so the movement is not passive. This facilitator serves three purposes. First, the external rotation may disadvantage or inhibit the tensor fascia latae and the ilio tibial band which is a femoral internal rotator. Second, the external rotation may recruit the deep hip intrinsic muscles. These fit the classification of local stabilizers by Comerford and Mottram (2001). Local stability muscles should functionally co-activate together (Richardson et al 1999), so activating the deep hip intrinsic muscles may facilitate the local stability role of psoas major. Thirdly, psoas and iliacus share a common tendon as they insert into the lesser trochanter and they may contribute to lateral rotation. In normal function the local and global muscles recruit synergistically. Low threshold activation of the global role of iliacus and the anterior fascicles of psoas through lateral rotation may facilitate the local function in the posterior fascicles of psoas.

2. Normal (unforced) end range expiration

During expiration the diaphragm ascends. With the anatomical relationship that exists between the diaphragm and psoas, expiration may create a mechanical pull on psoas via fascial connections.

3. Pelvic floor contraction

There is a strong anatomical relationship between the pelvic floor fascia and the inferior psoas fascia. A gentle pelvic floor contraction should be performed the same way it is used to facilitate transversus abdominis (Richardson et

Table 4: A list of the verbal cues and facilitation strategies used for the rehabilitation of psoas major

Verbal Cues	Low Load Facilitators	Movement & Load Facilitators
• Pull hip into the socket • Shorten hip • Pull knee towards hip • Pull ankle towards hip (+/- light resistance to ankle)	• Slight hip external rotation • Expiration • Pelvic floor contraction • Transversus abdominis contraction	• Side-lying rotation to neutral • Distraction – unilateral & bilateral • Sitting – leaning back • Hand – knee diagonal push

Table 5: The therapist observations and client feedback for an ideal performance of the psoas major motor control stability exercise

Observations from the therapist	Feedback from the client
• Observable movement of the femur or ankle approximately 1cm (due to superior – medial and posterior movement of the femoral head) • Palpation of transversus abdominis and lumbar multifidis • No palpable contraction of the quadriceps or sartorius in the antero-lateral groin • Neutral spine maintained • Normal breathing maintained • Holding time of 15 seconds for two repetitions for the assessment	• High confidence (greater than 70%) that the correct strategy was performed • No need for tactile feedback • A good understanding when to stop or if substitution is about to occur • Low sensation of effort with the initiation of the contraction and holding time (approximately 30% or less)

Table 6: Reasons for inability to achieve an efficient specific contraction of psoas major

Reason for poor activation of psoas major	Rehabilitation Options
1. Unable to understand specific exercise instructions	• Change cue or instruction • Use a movement and load facilitator • Train the global role of psoas major and iliacus • Use a different specific motor control stability exercise (i.e. transversus abdominis) • Change to proprioceptive exercises
2. Understands instructions, but can't generate a shortening action of the hip	• As above • Use low load facilitators • Change to proprioceptive exercises
3. Understands and can perform a shortening action of the hip, but is unaware of activation	• Increase concentration and effort • Shorten hip until point of substitution • Use low load facilitators
4. Understands and can perform a shortening action of the hip, but cannot identify substitution	• Increase concentration and effort • Use less force and a slower contraction • Change monitoring strategy to palpation of quadriceps, or iliac crest
4. Understands and can perform a shortening action of the hip, but activation is inefficient	• Increase concentration and effort • Shorten hip until point of substitution • Use low load facilitators
5. Understands and can perform a shortening action of the hip, but too much substitution	• Increase concentration and effort • Ensure activation is slow • Problem solving tips
6. Understands and can perform an efficient activation, but this causes pain	• Continue exercise until the point that pain increases • Train lumbar multifidis on the same side or psoas major on the opposite side • Use a different specific motor control stability exercise (i.e. transversus abdominis) • Train the global role of psoas major and iliacus • Myofascial trigger point release

Table 7: Common substitutions during the specific motor control stability exercise for psoas major with their problem solving strategies.

Substitution	Problem Solving Strategy
Dominant or excessive activation of rectus femoris	• Use less force and a slower contraction • A pillow may be used to put the knee in slight flexion to disadvantage rectus femoris
Dominant or excessive activation of TFL/ITB	• Use less force and a slower contraction • Ensure the hip external rotation is active rather than passive and slightly more effort may be used during the external rotation contraction • The hip may be placed in slight abduction to disadvantage TFL/ITB
Dominant or excessive activation of quadratus lumborum	• Use less force and a slower contraction • Ensure the spine is in neutral • Change position to long sitting
Dominant or excessive activation of iliocostalis	• Use less force and a slower contraction • There is excessive anterior tilt and spinal extension • Ensure the spine is in neutral
Dominant or excessive activation of proximal trunk muscles	• Significant resistance to passive rotation of the pelvis identifies this • Use less force and a slower contraction • Ensure low effort activity by the facilitators
Loss of neutral spine	• Ensure the spine is in neutral actively rather than passively after it is achieved • Use less force and a slower contraction
Loss of normal breathing	• Only perform the exercise within the range that normal breathing can be maintained • Change the priority to breathing control exercises

al 2004). This strategy does not appear to be useful if there is a pelvic floor dysfunction.

4. Transversus abdominis contraction
There is a strong fascial connection between transversus abdominis and psoas major (Gibbons 2004), therefore a transversus abdominis contraction may facilitate psoas major. This strategy will not be useful if the client is not able to achieve a conscious activation of transversus abdominis.

Movement and load facilitators
In situations where psoas major is dysfunctional or there is a lack of proprioception by the client, it is permissible to use movement and load facilitators. A dysfunction identified in psoas is a decrease in normal *low threshold* recruitment. Under higher load situations psoas will be activated. These can be used to facilitate psoas major and then the client can return to the normal low load facilitators. The above facilitation strategies can be used in conjunction with the movement and load facilitation strategies if necessary.

1. Side-lying rotation to neutral (psoas major co-activation with multifidus)
The client is positioned in side lying with the dysfunctional (or suspected side) side of psoas uppermost. Both hips are flexed to approximately 65° with the spine and pelvis in neutral alignment in terms of tilt and rotation. The client is instructed to allow the top leg to slide along the bottom leg approximately 10cm (i.e. the top femur slides along the bottom femur). This will cause the spine to move out of neutral. Psoas major is facilitated by gently distracting the top leg longitudinally and the patient is instructed to pull the hip back into the socket until the trunk and pelvis rotates back to the neutral position. The segmental or oblique fibres of multifidus are co-activated by the direct rotational movement. The technique can be segmentally localized by manual fixation at the level above the dysfunction.

2. Bilateral distraction with pelvic hanging

The client sits at the edge of the bed and takes their body weight through their hands and moves forward so that their sacrum is touching the edge of the bed for feedback, the pelvis is unsupported providing distraction and the spine is in a neutral position. This is inappropriate if the client is pushing excessively through the feet or there is bracing of the abdominals. Psoas is facilitated by instructing the patient to pull the hip back into the socket without moving the spine or pelvis. An alternate instruction would be to "pull the patella back away from a finger". Check for co-contraction rigidity by passively rotating the leg and observe for normal relaxed breathing. It is normal to have global muscle co-activation during this strategy (i.e. quadriceps activation), however, it should be mild and should not create rigidity.

3. Unilateral distraction with leg hanging

The client stands at a corner of a wall so that their back is against the wall and the shoulder on the side to be facilitated is against the side of the wall. They stand on a book and let the leg closest to the wall hang unsupported off the book. The wall should support the shoulder on this same side. The lumbar spine and pelvis need to be in neutral. This is inappropriate if the client cannot maintain neutral. Allow the unsupported leg to relax so that there is gentle gravity distraction and monitor the ASIS to keep a neutral pelvis. Psoas major is facilitated by instructing the patient to pull the hip back into the socket without moving the spine or pelvis. Check for co-contraction rigidity by passively rotating the leg and observe for normal relaxed breathing.

4. Sitting – leaning back (eccentric hip flexors)

The client sits with the spine and pelvis in neutral and the feet on the floor. Keeping the spine and pelvis neutral the patient is instructed to slowly lean backwards by only moving at the hips (rock from the ischium). This requires that the deep hip flexors eccentrically lower the trunk backwards. Ensure that the lumbo-pelvic neutral alignment is maintained. In this position, psoas major is facilitated by instructing the patient to pull the hip back into the socket without moving the spine or pelvis. Check for co-contraction rigidity by passively rotating the leg and observe for normal relaxed breathing. It is normal to have global muscle co-activation during this strategy (i.e. oblique abdominal activation), however, it should be mild and should not create rigidity. There should be no substitution dominance from the hip flexor mobilisers (anterior tilt of the pelvis) or the abdominals (trunk flexion and posterior pelvic tilt), and there should be no fatigue. This is also a useful strategy without the shortening action of psoas major due to strong co-activation of psoas major.

5. Hand – knee diagonal push

The client is in crook lying with the spine supported in neutral. They slowly lift one knee towards the opposite hand and push them isometrically against each other on a diagonal line *(watch for substitution e.g.* do not stabilise with the opposite foot or allow posterior pelvic tilt). Ensure that the neutral spine position is maintained. Psoas major strongly co-activates with multifidus in this procedure. This technique uses significant more global stabilizer co-contraction than many of the others and is a useful strategy without the shortening action of psoas major due to strong co-activation of psoas major. This may be appropriate when significant inhibition is present (e.g. post surgery or inflammatory trauma).

As the facilitation strategies become more familiar, and efficient activation can be achieved, the facilitation techniques should be gradually discarded. To make the exercises more challenging, retraining should be progressed to a conscious activation with a more efficient specific contraction. As a guide, the exercises should move away from the movement and load facilitators, to the low load facilitators, towards conscious activation and a greater cognitive challenge like integration into function.

Stage 2a: Assessment of the Local Stability Role for the Lumbar Spine

When the action of psoas major has been correctly been taught and can be performed the assessment of the local stability role (segmental stabilizing role) of psoas major can start.

The client lies prone on the plinth with the lumbar spine in a neutral position. A pillow may be placed under the hips to help for comfort or to help relax any paraspinal muscle activity. Each lumbar vertebral level is manually palpated to assess the relaxed joint play displacement in the transverse and anterior directions.

Psoas major is facilitated by instructing the patient to 'pull the hip back into the 'socket' (use the best verbal cue from stage 1a) without moving the spine or pelvis. This gentle contraction is sustained. Here, the therapist should check for the correct technique. The same monitoring technique can be used in this position (ASIS and anterior lateral groin) and the therapist can observe for over activity in the erector spinae. When the correct technique can be performed in prone, each lumbar vertebral level is re-palpated to assess the contracted joint play in the transverse and anterior directions. Ideally, there should be a significant palpable increase in resistance to manual displacement (stiffness) at each level with psoas major activation. The client should be able to maintain the contraction (and increased stiffness) for fifteen seconds with normal relaxed breathing and without fatigue or substitution. This response should be noted at all lumbar segmental levels.

Segmental psoas major dysfunction is identified at the vertebral level in which there is no increased resistance to manual displacement during psoas major activation when compared to adjacent levels (which do increase resistance to translation when psoas major is activated). This lack of resistance to manual displacement indicates a probable loss of segmental control of the local stability role of psoas major (Gibbons et al, 2002). This assessment may also be performed in other positions (i.e. side lying) so long as distraction of the hip is controlled and there is no over activation of the paraspinal muscles.

Note: If the client is using facilitation techniques during the assessment to activate psoas major, the palpation should be performed with and without the facilitators for comparison. It is possible to facilitate other local stability muscles, which may affect the palpation component of the assessment. For example, a pelvic floor contraction may facilitate transversus abdominus.

Stage 3a: Specific Motor Control Stability Retraining for Psoas Major

Once the correct activation can be accomplished, retraining is performed in a variety of different positions. Clinically, it may be best to start in a position where the client is confident they can achieve a correct activation, rather than what the therapist feels is the best activation. For the majority of patients, recumbent postures, such as supine lying, incline sitting or side lying, are the positions where it is easiest to facilitate and teach the correct activation of psoas major. Other positions can be used as the current ones become easy. Another useful strategy for psoas major retraining is to combine it with other components of the lumbar cylinder. The specific motor control stability exercise for psoas major should also be trained with transversus abdominis, the pelvic floor, deep multifidus and the diaphragm. As a general guide, the psoas contraction should be maintained for ten seconds and for ten repetitions, during normal relaxed breathing. Two or three sets a day are reasonable, depending on the client. The local stability (segmental stability) of psoas major should be reassessed (Stage 2a) regularly to ensure appropriate progression.

Stage 4a: Integration of Specific Motor Control Stability Retraining into Function

When the retraining in stage 3a becomes efficient and is easily activated it can be readily

integrated into functional activities. It is easier to start with static activities such as standing or sitting and it is best to start supported and progress to unsupported. When this becomes easier, it can be incorporated into dynamic movements such as bending or walking (stairs are useful). Functional integration may include activities of daily living, work or sport related activities and previous activities that were provocative (within a pain free range). At any time a proprioceptive challenge can be included.

Rothstein (1982) has suggested that to integrate an activity or skill into normal, automatic or unconscious function, many repetitions must be performed under diverse functional situations. To do this, some form of 'reminder' is needed. He has proposed that small 'red dots' are placed so that they are frequently seen and will 'remind' the subject to perform a specific task each time they are observed. This process lends itself well to training of the local stability system.

This process is repeated each time that a red dot is sighted. Place lots of red dots in appropriate positions (e.g. wristwatch, clock, telephone, coffee/tea making area, office drawer, bathroom mirror, under refrigerator door seal, red traffic light). The red dot is a visual reminder (a telephone ring or emergency vehicle siren could be an auditory reminder) to perform the exercise. It is important the client continue their functional activity when retraining psoas major into function, and not 'stop' and then activate. This may hinder incorporation of psoas major into function.

Stage 1b. Instruction of the Global Stability Role of Psoas Major and Iliacus Function
The client is taught how to position the lumbar spine in neutral while in sitting with the feet on the floor and the hips 10° higher than the knees. This typically involves a combination of the thoracic spine and lumbar spine moving independently of each other to produce a lumbar lordosis (or place the lumbar spine in a mid range position if the range is not available).

A common substitution strategy is a thoraco-lumbar lordosis with a dominance of the lumbar extensor mobilizer muscles. The client is observed flexing the hip and the substitution strategy (or strategies) identified. The client is then taught to avoid substitution and flex the hip towards the chest without losing the neutral spine position.

Stage 2b. Assessment of the Global Stability Role of Psoas Major and Iliacus Function
The global stability role of psoas major (anterior fascicles) is functionally combined with iliacus. Psoas major contributes to hip flexion, while iliacus is the dominant stabilizing hip flexor. This may be considered efficient when these muscles can move the limb through the available passive range of 120° hip flexion. The superior fibers of iliacus can flex the hip to this range, while the role of psoas major becomes less of a hip flexor and more of a stabilizer of the lumbar lordosis in this position. In sitting with the lumbar spine in neutral, the hip is actively flexed through the full range of motion (ideally 120°). There should be no loss of lumbo-pelvic neutral or co-contraction of TFL / ITB and sartorius, or the hamstrings. This can be identified as significant resistance to passive rotation of the hip when it is flexed. In optimum function, this position should be maintained for ten seconds and ten repetitions with normal breathing (it is recognized that there may be other reasons why there is a loss of a neutral spine during this test). It is uncommon to see a client with low back pain pass this test.

Stage 3b. Retraining of the Specific Movement Stability Role
The specific movement stability role (global role) of psoas major and iliacus is best started in supine lying (or long sitting) with a heel slide. The heel actively slides up beside the opposite leg towards the buttock (as far as the contralateral knee) while maintaining a neutral lumbar spine. The eccentric return (straightening of the leg) should be controlled and performed at the same slow pace as the concentric component. The client should be

taught to also monitor tibial external rotation, hip internal rotation and hip adduction (signs of TFL / ITB dominating hip flexion) and lateral hip rotation (a sign of sartorius dominating hip flexion). The therapist should also check for co – contraction rigidity at the point the hip is held. This movement is performed ten – fifteen repetitions. Once the heel slide can be coordinated and reach the opposite knee, the foot can be lifted 2cm and held and gradually progressed to 90° hip flexion. From here the exercise can be progressed to supported standing, unsupported standing, high sitting and then the test position.

Psoas also has an eccentric role in spinal stability. This can be started in sitting during a lean backwards and then in standing. Standing and side bending of the trunk is also controlled by psoas major and is best started supported at a wall with the spine in neutral and then progressed to unsupported standing.

Stage 4b. Integration of Specific Movement Stability Retraining into Function
This follows along the same concept as described above for stage 4a. When the retraining in stage 3b becomes efficient it can be readily integrated into functional activities. As with the local role, it is easier to start with static activities such as standing or sitting and it is best to start supported and progress to unsupported. When this becomes easier, it can be incorporated into dynamic movements such as walking and stepping.

Stage 5. Integration of Local and Global Co-activation into Normal Function
Here, the local stability role of psoas major is combined with the global stability role. 'Shortening the hip' activates psoas, and then while maintaining this action, slow heel slides are started. In this stage the hip should slide only as far as the client confidently feels that the hip is still 'shortened' and held for ten seconds for ten repetitions. The integration of the local and global role takes the same progression as stage 4a and 4b.

Conclusion
This paper provides an overview of the function of psoas major as a background for the therapeutic rationale for a role in lumbo-pelvic stability. The rehabilitation of the local and global stability roles of psoas major are described in detail for the lumbar spine. A similar approach for psoas major may be applied to the sacroiliac joint, hip and pelvic floor rehabilitation. It should be noted that the local and global role of psoas major may be trained independently of each other or concurrently. This is a clinical decision for the therapist, however it is recommended that rehabilitation addresses both aspects of stability at different stages or concurrently. Further research is required to consider psoas major as part of the lumbar cylinder mechanism and to ensure the described exercise corrects the observed dysfunction in psoas major. This may help dispel some common beliefs about psoas major and provide a new rehabilitation option for lumbo-pelvic and hip pain.

References

Andersson EA, Nilsson J, Thorstensson A 1997 Intramuscular EMG from the hip flexor muscles during human locomotion. Acta Physiol Scand 161:361-370

Andersson E, Oddsson L, Grundstrom H et al 1995 The role of the psoas and iliacus muscles for stability and movement of the lumbar spine, pelvis and hip. Scand J Med Sci Sports 5:10-16

Bachrack RM, Nicelorra J, Winuk C 1991 The relationship of low back pain to psoas insufficiency. Journal of Orthopedic Medicine 13(2):34-40

Barker KL, Shamley DR, Jackson D 2004 Changes in the cross sectional area of multifidus and psoas in patients with unilateral back pain. Spine 29(22):E515-E519

Bartlink DL 1957 The role of intra-abdominal pressure in relieving the pressure on the lumbar vertebral discs. Journal of Bone and Joint Surgery 39B:718-725
Bogduk N, Pearcy M and Hadfield G 1992 Anatomy and biomechanics of psoas major. Clinical Biomechanics 7:109-119

Comerford MJ, Mottram SL 2001 Movement and stability dysfunction – contemporary developments. Manual Therapy 6(1):15-26

Dangaria TR and Naesh O 1998 Changes in cross-sectional area of psoas major muscle in unilateral sciatica caused by disc herniation. Spine 23(8):928-931

Dostal WF, Soderberg GL, Andrews JG 1986 Actions of hip muscles. Physical Therapy 66(3):351-361

Ferreira PH, Ferreira ML, Maher CG, Herbert RD Refshauge K 2006 Specific stabilization exercise for spinal and pelvic pain: A systematic review. Australian Journal of Physiotherapy 52:79-88

Gibbons SGT 1999 A review of the anatomy, physiology and function of psoas major: A new model of stability. Proceedings of: 11th Annual National Orthopaedic Symposium. "The Tragic Hip: Trouble in the Lower Quadrant". Nov 6-7, Halifax, Canada.

Gibbons SGT 2004 A Hypothetical Link Between Psychosocial Factors, Pain and Sensory Motor Function using a Biomechanical Model of Psoas Major. MSc Thesis in Health Ergonomics, University of Surrey

Gibbons SGT 2005 Muscle function – A critical Evaluation. Proceedings of: The 2nd International Conference on Movement Dysfunction. "Pain and Performance: Evidence & Effect". September 23rd – 25th, Edinburgh, Scotland

Gibbons SGT 2001 The model of psoas major stability function. Proceedings of: 1st International Conference on Movement Dysfunction. Sept 21-23, Edinburgh, Scotland.

Gibbons SGT 2007 A randomized controlled trial of specific motor control stability exercise versus specific directional exercises in acute low back pain. New directions towards prognostic indicators. Submitted

Gibbons SGT, Comerford MJ, Emerson P 2002 Rehabilitation of the stability function of psoas major. Orthopaedic Division Review Jan / Feb: 7-16

Gibbons SGT, Holmes MWR, Grandy C, Kean C, Behm DG 2007 Altered hip and trunk muscle recruitment in subjects with chronic low back pain during a specific exercise for the psoas major muscle. Submitted

Gibbons SGT, Pelley B and Molgaard J 2001 Biomechanics and stability mechanisms of psoas major. Proceedings of: 4th Interdisciplinary World Congress on Low Back Pain. November 9-11, Montreal, Canada.

Gracovetsky S, Farfan HF, Lamy C 1981 The mechanism of the lumbar spine. Spine 6(3):249-262

Hides JA, Stokes MJ, Saide M, Jull GA and Cooper DH 1994 Evidence of lumbar multifidus muscle wasting ipsilateral to symptoms in patients with acute/subacute low back pain. Spine 19(2):165-172

Hodges PW, Richardson CA, and Gandevia SC 1997 Contractions of specific abdominal muscles in postural tasks are affected by respiratory maneuvers. Journal of Applied Physiology 83(3):753-760

Hodges P, Kaigle Holm A, Holm S et al 2003 Intervertebral stiffness of the spine is increased by evoked contraction of transversus abdominis and the diaphragm: in vivo porcine studies. Spine 28(23):2594-2601

Janevic J, Ashton-Miller JA , Schultz AB 1991 Large compressive pre-loads decrease lumbar motion segment flexibility. Journal of Orthopedic Research 19:228-236

Juker D, McGill S, Kropf P et al 1998 Quantitative intramuscular myoelectric activity of lumbar portions of psoas and the abdominal wall during a wide variety of tasks. Medicine & Science In Sports & Exercise 30(2):301-310

Jull G 2000 Deep cervical flexor muscle dysfunction in whiplash. Journal of Musculoskeletal Pain 8(1/2):143-154

Maher CG, Latimer J, Hodges PW, Refshauge KM, Moseley GL, Herbert RD, Costa LOP, McAuley J 2005 The effect of motor control exercise versus placebo in patients with chronic low back pain. BMC Musculoskeletal Disorders 6:54

McGill S 2002 Low Back Disorders. Evidence-Based Prevention and Rehabilitation. Human Kinetics, Champaign, IL

McGill SM, Patt N and Norman RW 1988 Measurement of the trunk musculature of active males using CT scan radiography: Implications for force and moment generating capacity about the L4/L5 joint. Journal of Biomechanics 21:329-341

Morris JM, Lucas DB and Bresler B 1961 Role of the trunk in stability of the spine. The Journal of Bone and Joint Surgery 43A:327-351

Moseley GL, Hodges PW, Gandevia SC 2002 Deep and superficial fibers of the lumbar multifidus muscle are differentially active during voluntary arm movements. Spine 27(2):E29-E36

Nachemson A 1968 The possible importance of the psoas muscle for stabilisation of the lumbar spine. Acta Orthopaedica Scandinavica 39:47-57

O'Sullivan PB, Twomey L, Allison G et al 1997 Altered patterns of abdominal muscle activation in patients with chronic low back pain. Australian Journal of Physiotherapy 43(2):91-98

Rab GT, Chao EYS, Stauffer RN 1977 Muscle force analysis of the lumbar spine. Orthopaedic Clinics of North America 8(1):193-199

Richardson C, Hodges P Hides 2004 Therapeutic Exercise for Lumbopelvic Stabilization 2nd Edn. Churchill Livingstone, Edinburgh

Richardson C, Jull G, Hides J, Hodges P 1999 Therapeutic Exercise for Spinal Stabilisation: Scientific basis and practical techniques. Churchill Livingstone, Edinburgh

Richardson CA, Snijders CJ, Hides JA 2002 The relation between the transversus abdominis muscles, sacroiliac joint mechanics, and low back pain. Spine 27:399-405

Rothstein JM 1982 Muscle biology. Clinical Considerations. Physical Therapy 62(12): 823-30

Rothstein J, Roy S, Wolf S 1991 The Rehabilitation Specialist's Handbook. F.A. Davis.

Sahrmann S A 2002 Diagnosis & Treatment of Movement Impairment Syndrome. Mosby USA

Santaguida PL, McGill SM 1995 The psoas major: a three dimentional geometric study. Journal of Biomechanics 28:339-345

Sapsford RR, Hodges PW, Richardson CA, Cooper DH, Markwell SJ, Jull GA 2001 Co-activation of the abdominal and pelvic floor muscles during voluntary exercises. Neurology and Urodynamics 20:31-42

Shirley D, Hodges PW, Eriksson AEM, Gandevia SC 2003 Spinal stiffness changes throughout the respiratory cycle. Journal of Applied Physiology 95:1467-1475

Snijders CJ, Vleeming A, Stoeckart R et al 1995 Biomechanical modeling of sacroiliac joint stability in different postures. Spine: State of the Art Reviews 9(2):419-432

Williams PL, Warwick R, Dyson M and Bannister 1989 Gray's Anatomy 37th ed. Churchill Livingstone, Edinburgh

Yoshio M, Murakami G, Sato T et al 2002 The function of the psoas major muscle: passive kinetics and morphological studies using donated cadavers. Journal of Orthopaedic Science 7: 199 – 207