

Spinal Stabilisation

4. Muscle Imbalance and the Low Back

Christopher M Norris

Summary

Muscle imbalance occurs when muscles become constantly shortened or lengthened in relation to each other. Various imbalance classifications have been suggested relating to muscles' structure, function and response to injury. Muscles have been classified as both postural and phasic types, and stability and movement synergists. A shortened muscle in a group shows a lowered irritability threshold and is recruited first in a movement, causing changes in motor programming. A muscle lengthens by the addition of sarcomeres, and its peak tension occurs only in a lengthened position. Lengthened muscles may be shortened by splinting them and/or contracting them within inner range. Shortened muscles may be stretched using proprioceptive neuromuscular facilitation (PNF) techniques.

Stabilising muscles may be retrained by working them at low loads for sustained contractions of 10 seconds. Fatigue encourages unwanted phasic activity and should be avoided. Posture assessment is described, and lordotic, swayback, kypho-lordotic, and flatback postures are examined. Muscle length assessment is described for those hip muscles having actions over the pelvis or lumbar spine. Stretching exercises for the iliopsoas, rectus femoris, hip adductors, quadratus lumborum, hip rotators, piriformis, and hamstrings are described and illustrated. Movement pattern assessment for trunk flexion, hip extension, and hip abduction is described.

Key Words

Muscle length, posture, motor programme, exercise.

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Introduction

The stabilising systems of the lumbar spine include an active mechanism provided by muscles. Muscles produce and control movement and so are essential to the normal functioning of the spine. Traditionally, manual techniques for the spine within physiotherapy have focused on joints, with little emphasis being placed on the importance of muscles. However, normal movement depends not only on passive joint mobility, but also on active stability. For this reason, the physiotherapist must

deal with both muscle length and strength, and be able to identify and correct faulty movement patterns which affect the lumbar spine. It is the quality of a movement rather than simply strength alone which is important to the muscle imbalance process.

The concept of muscle imbalance has been described by various authors (Kendall *et al*, 1993; Janda and Schmid, 1980; Sahrman, 1987a; Richardson, 1992). In its simplest form it is the ratio between the strength or flexibility of the agonist and antagonist muscles acting over a joint (Kendall *et al*, 1993). More in-depth descriptions of imbalance categorise muscles into specific groups, depending on structure, function and response to injury or loading.

Classification into Postural and Phasic Types

Classification of muscles into postural and phasic types (table 1) is dependent on the muscles' reaction to physical stress and injury (Janda and Schmid, 1980; Jull and Janda, 1987). Postural muscles show an increased tendency to tighten. In general these muscles are usually bi-articular, and proportionally stronger than their phasic counterparts. As well as reducing range of motion, the tightened muscle is more likely to develop painful trigger points (Travell and Simons, 1983). These are small hypersensitive regions within a muscle

Table 1: Postural and phasic muscle classification (Jull and Janda, 1987)

Muscles	Characteristics
Postural	
Quadratus lumborum	Tend to tighten
Erector spinae	Bi-articular
Iliopsoas	One-third stronger
Tensor fascia latae	Trigger points
Rectus femoris	Lower irritability threshold
Piriformis	
Pectineus	
Adductors	
Hamstrings	
Gastrocnemius	
Soleus	
Tibialis posterior	
Phasic	
Rectus abdominis	Tend to lengthen
Internal and external obliques	Weak
Gluteals	Uni-articular
Quadriceps	
Tibialis anterior	
Peronei	

which stimulate afferent nerve fibres causing pain. The sensation created is a deep tenderness with an overlying increase in tone creating a palpably tender band of muscle. When palpated deeply, the trigger point creates a local muscle spasm giving the 'jump sign' (Janda, 1993).

The irritability threshold of a tight muscle is lowered, causing it to be activated earlier than normal in a movement sequence. One of the reasons for this is that being tight there is less 'slack' to take up in the muscle before contraction begins. In addition, the muscle shows an increased afferent input *via* the stretch receptors (Sahrmann, 1990). Overactivity of a tight muscle may result in reciprocal innervation of its antagonist, and a reprogramming of the total motor sequence, a process termed pseudoparesis (Janda, 1986). Attempts to strengthen a muscle inhibited in this way can be ineffective. However, stretching can cause a spontaneous disinhibition, and a more normal reaction to resistance may follow (Jull and Janda, 1987).

Phasic muscles, which are antagonistic to the postural type, show a tendency to 'weaken' and lengthen with inactivity and also following injury. This reaction has been termed stretch weakness (Kendall *et al*, 1993). The muscle has remained in an elongated position, beyond its normal resting position, but within its normal range. This is differentiated from over-stretch where a muscle is simply elongated or stretched beyond its normal range.

From a structural standpoint, long-term elongation of a muscle causes it to lengthen by the addition of up to 20% more sarcomeres (Gossman *et al*, 1982). The length-tension curve of a lengthened muscle moves to the right (fig 1). The peak tension such

a muscle can produce in the laboratory situation is up to 35% greater than that of a normal length muscle (Williams and Goldspink, 1978). However, this peak tension occurs at approximately the position where the muscle has been immobilised (point A, fig 1). If the strength of the lengthened muscle is tested with the joint in mid-range or inner-range (point B, fig 1), as is common, it cannot produce its peak tension, and so the muscle appears 'weak'. For this reason, isometric manual muscle tests may more accurately be considered as indicators of positional strength, rather than total strength or tension development (Sahrmann, 1987b).

In the laboratory situation the lengthened muscle will return to its optimal length within approximately one week if placed in a more shortened position once more (Goldspink, 1992). Clinically, restoration of optimal length may be achieved by either immobilising the muscle in its physiological rest position (Kendall *et al*, 1993), and/or exercising it in its shortened (inner range) position (Sahrmann, 1990). Enhancement of strength is not the priority in this situation, indeed the load on the muscle may need to be reduced to ensure correct alignment of the various body segments and correct performance of the relevant movement pattern.

The exact reason for the differences between postural and phasic muscle types is not clear, but a number of possibilities exist. An alteration in the central nervous system control to the muscles has been proposed, because the postural muscles are those which commonly show spasticity in hemiplegia (Jull and Janda, 1987). It has also been suggested that the distribution of the differing fibre types within the muscle may be an important factor (Oliver and Middleditch, 1991).

Muscle responses which may ultimately lead to an imbalance can be seen as a result of both acute pathology and an impairment in motor control. Acute pathology will cause swelling and pain. Swelling has been shown to cause a reflex inhibition of muscles in the knee (de Andrade *et al*, 1965; Stokes and Young, 1984), and similar results may occur elsewhere in the body. Pain will encourage the patient to take up a position which will reduce tissue stress and so lessen the pain. When the pain has resolved, habitual alteration in posture often remains.

Alteration in motor control may occur for three reasons (Jull and Janda, 1987). First, a change in muscle tone can result from stimulation of the limbic system due to emotional factors and stress. Secondly, impairment of afferent input through a reduction in proprioception can alter muscle function around a joint. Thirdly, developmental factors are important. Some individuals appear to

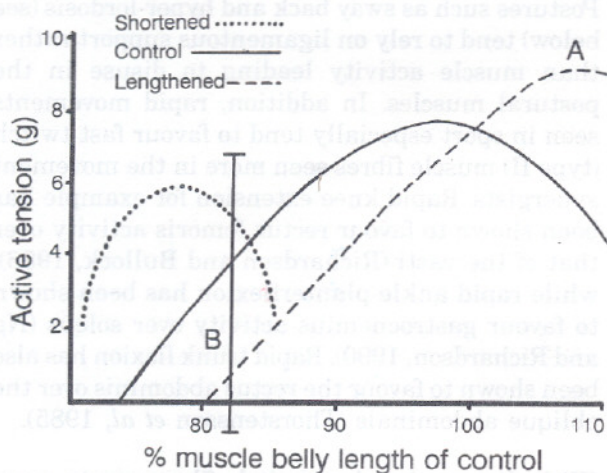


Fig 1: Effects of immobilising a muscle in shortened and lengthened positions (Gossman *et al*, 1982)

The normal length tension curve (control) moves to the right for a lengthened muscle, giving it a peak tension some 35% greater than the control (point A). When tested in an inner range position however (point B), the muscle tests weaker than normal

have poor motor control in general and are clumsy when performing physical tasks. Interestingly, in a study assessing chronic low back pain sufferers, a diagnosis of minimal cerebral dysfunction was made for 80% of the subjects (Janda, 1978).

The disposition to muscle weakness/tightness is not random, but can occur in specific muscle imbalance patterns, focused around the pelvic and shoulder girdles. An important imbalance pattern in the lumbar region is the pelvic crossed syndrome (PCS). This is demonstrated by a combination of tightness in the short hip flexors and erector spinae and weakness in the abdominal and gluteal muscles (Janda and Schmid, 1980). PCS leads to an increased pelvic tilt, often resisted by shortening of the hamstrings (fig 2).

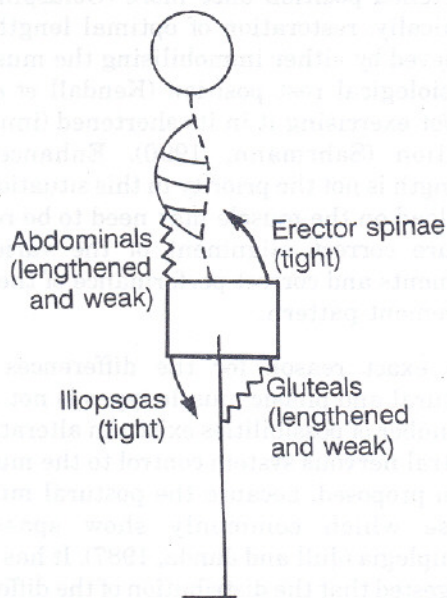


Fig 2: The pelvic crossed syndrome (Janda and Schmid, 1980)
In a lordotic posture, tightness of the iliopsoas and spinal extensors combines with lengthening of the abdominal muscles and hip extensors. The resultant anterior tilt of the pelvis is often resisted by tension in the hamstring muscles

Classification into Movement Synergist and Stability Synergist

A further muscle classification relating to imbalance is that of movement synergists and stability synergists (Richardson, 1992) (table 2).

Table 2: Examples of stability and movement synergists (Richardson, 1992)

Stability synergist	Movement synergist
Iliopsoas	Tensor fascia lata
Gluteus maximus	Rectus femoris
Gluteus medius	Hamstrings
Vastus medialis obliquus	
Soleus	Gastrocnemius
Deep neck flexors	Superficial neck flexors
Transversus abdominis	Rectus abdominis
Internal oblique	
External oblique	

This classification considers the anatomical site of the muscle and its biomechanics, physiological and biochemical properties, and the overall motor programming of a movement in which the muscle is involved. There is much overlap with the postural and phasic classification but some important differences.

From the point of view of active lumbar stabilisation, the stability synergist is of prime importance. In the case of the trunk, the stability synergists are the transversus abdominis and the internal and external obliques. The rectus abdominis is considered a movement synergist. The stability synergist is often a single joint muscle aligned to oppose gravity and approximate a joint. These muscles tend to be deep and have extensive aponeuroses rather than long tendons. The stability synergist demonstrates properties associated with slow twitch (type I) muscle fibres being able to control low force levels for long periods. Properties of muscle fibre type are listed in table 3.

Table 3: Characteristics of muscle fibre types (Stokes and Cooper, 1993; Richardson, 1992)

Characteristic	Type I	Type II
Myosin ATPase activity	Low	High
Contraction/relaxation rate	Slow	Fast
Firing frequency	5-20 Hz	30-100 Hz
Type of contraction	Tonic	Phasic
Discharge type	Continuous	Bursts
Recruitment threshold	Low	High
Muscle function	Stabiliser	Mobiliser
Fatigue	Resistant	Fast
Myoglobin and capillary content	High > red	Low > white
Mitochondria	Many	Few
Metabolism	Oxydative	Glycolytic

Postures such as sway back and hyper-lordosis (see below) tend to rely on ligamentous support rather than muscle activity leading to disuse in the postural muscles. In addition, rapid movements seen in sport especially tend to favour fast twitch (type II) muscle fibres seen more in the movement synergists. Rapid knee extension for example has been shown to favour rectus femoris activity over that of the vasti (Richardson and Bullock, 1986), while rapid ankle planterflexion has been shown to favour gastrocnemius activity over soleus (Ng and Richardson, 1990). Rapid trunk flexion has also been shown to favour the rectus abdominis over the oblique abdominals (Thorstensson *et al*, 1985).

With disuse, the slow twitch fibres waste more quickly than the fast twitch fibres, and begin to take on the characteristics of the fast twitch type (Richardson, 1992). The reduction in slow twitch fibre function means that the stability synergist has a reduced endurance capacity, and under the

effect of gravity will tend to lengthen.

To retrain the stability synergist three stages are involved. In stage 1 the stability synergist is isolated and activated, normally in the classical muscle test position (Kendall *et al*, 1993). In stage 2 slow twitch muscle fibre function is retrained. This is achieved by using isometric loading short of fatigue. Low loads are used, between 20-30% of maximum voluntary contraction (MVC). The contraction is sustained for ten seconds and repeated several times. Continuous holding, although capable of enhancing muscle endurance, is not used because fatigue would create a jerky phasic action of the muscles, brought on by substitution from fast twitch fibre contraction. A lengthened muscle should be actively contracted in a posturally shortened position (White and Sahrman, 1994). Maintenance of a corrected posture rehearses the motor skill required to maintain the posture, an important determinant of training specificity (Norris, 1993). Taping or splinting may be required to prevent continued lengthening throughout the day when the active effort of the patient lapses (White and Sahrman, 1994). Stage 3 of the retraining process is to work the synergists more functionally in association with each other. The load is increased and slow isotonic movements introduced. Eccentric activity is used, and proprioceptive training is begun. Eventually rate of movement is developed to a speed which matches the functional requirements of the patient.

The importance of the muscle imbalance process lies not in the classification of muscle types, but in the assessment and management of a patient. It is important first to identify shortened or lengthened muscles. Then the elongated muscle must be shortened. Tight muscles must then be stretched to restore the balance of muscle length and tension across a joint. After that, faulty motor programmes must be corrected and incorporated into patients' daily activities (Sahrman, 1987b, 1990).

Assessing Muscle Imbalance

Before prescribing exercises for the lumbar spine, it is important that an assessment is made of muscle function. The use of standard lists of exercises for the spine is a severe clinical error (Morgan, 1988). Until the present state of muscle function has been established, a subject's requirements for exercise cannot possibly be known.

Assessment procedures for muscle imbalance are drawn from Jull and Janda (1987), Lewit (1991), Kendall *et al* (1993), and Richardson (1992). Standing posture is assessed, together with

muscle tightness, and movement patterns. In addition the ability of a stability synergist to hold a static contraction is determined.

Assessment of Standing Posture

Standing posture is assessed in comparison to a standard reference line (Kendall *et al*, 1993). The subject is positioned with a plumb-line passing just in front of the lateral malleolus. In an ideal posture this line should pass just anterior to the midline of the knee, and then through the greater trochanter, bodies of the lumbar vertebrae, shoulder joint, bodies of the cervical vertebrae, and the lobe of the ear.

When viewed from the front, with the feet three inches apart, the line should bisect the body into two equal halves. The anterior superior iliac spines (ASIS) should be in the same horizontal plane, and the pubis and ASIS should be in the same vertical plane (Kendall *et al*, 1993). Anatomical landmarks are compared for horizontal level on the right and left sides of the body, and include the knee creases, buttock creases, pelvic rim, inferior angle of the scapulae, acromion processes, ears, and the external occipital protuberances. In addition the alignment of the spinous processes and rib angles is observed, with minor scoliosis becoming more evident when assessed in Adam's position. The distance between the arms and the trunk, skin creases, and unequal muscle bulk are indicators of asymmetry requiring closer examination. Foot and ankle alignment are also assessed.

Four posture types are commonly seen (fig 3); Kendall *et al* (1993) and Norris (1994) give a more detailed description of these. The lordotic posture equates with the pelvic crossed syndrome described by Janda and Schmid (1980) in which the iliopsoas is shortened and the abdominal muscles lengthened. This is also known as the military posture and is commonly seen in young gymnasts and dancers. In addition it is the posture most noticeable after childbirth. Where the lordotic posture is due to obesity and poor muscle tone, the thoracic spine often moves into kyphosis as well, giving the kypho-lordotic (hollowback) posture. This may represent an imbalance surrounding the shoulder girdle described as the upper crossed syndrome. The reader is referred to Janda (1994) for a review of the effects of muscle imbalance on the shoulder girdle and upper spine.

In the sway back posture iliopsoas is likely to be lengthened due to the extended hip position, and weakened due to the reliance on ligament elasticity rather than muscle activity to maintain the posture. The sway back posture may be combined with dominance of one leg in standing ('hanging on the hip') especially in the adolescent. Now,

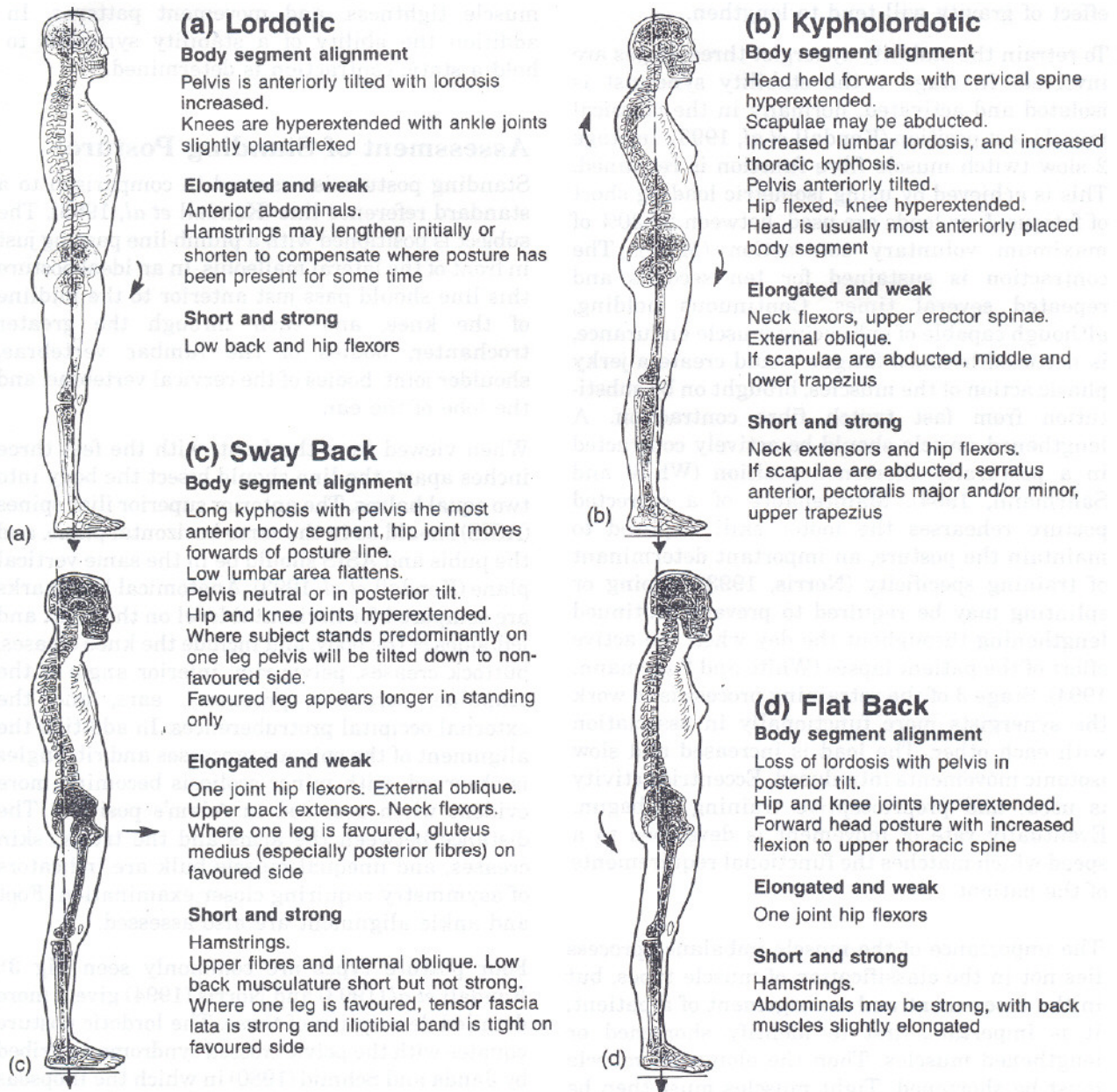


Fig 3: Posture types and muscle imbalance Kendall *et al*, 1993)

When a subject is viewed from the side and compared to a standard posture line (see text), four main posture types may be found. These are associated with shortened and lengthened muscles as shown.

weakness in the gluteus medius allows the pelvis to tip laterally, a situation partially compensated for by increased tone in the tensor fascia lata. Shortening is seen in the ilio-tibial band (ITB) with a prominent groove apparent on the lateral aspect of the thigh.

With the flat back posture, the main problem is lack of mobility in the lumbar spine and a flattening of the lordosis. This posture reflects the extension dysfunction described by McKenzie (1981).

Assessment of Muscle Tightness

Only tightness of those muscles directly attaching to the pelvis or lumbar spine is covered in this article. However, the reader is reminded that through the kinetic chain, structures distant to



Fig 4: The Thomas Test. Subject shows tightness in left iliopsoas and left rectus femoris

the trunk region may also change. The function and alignment of these structures may also be assessed.

Range of motion in the hip flexors may be assessed by the Thomas test (fig 4). During this manoeuvre the resting position of the lower leg determines inflexibility. Initially both legs are flexed to tilt the pelvis backwards and flatten the lumbar spine. The right leg is then straightened while being supported by the physiotherapist. At the same time the left knee is gripped firmly to the patient's chest to maintain the pelvic position and avoid an anterior pelvic tilt.

Hip flexor tightness is indicated if the knee of the lower leg rests above hip level in the horizontal plane. If the rectus femoris is shortened, knee flexion will be reduced from a normal value of 90°. Where the ITB is tight, the leg will rest in a slightly abducted position with the patella deviated laterally. ITB tightness may be more closely assessed by the Ober manoeuvre (see Norris, 1993a). Tightness in the medial or lateral hip rotators will show as a deviation of the lower leg away from the vertical, and this can be more closely assessed in prone lying with the knees flexed.

Hamstring length is determined by the straight leg raise (SLR) with the contralateral leg flexed at the hip and knee. The resting leg must remain on the supporting surface, and pure hip flexion should occur with no abduction or rotation. End range is reached when the ipsilateral knee begins to flex or the pelvis begins to tilt posteriorly. Allowing the pelvis to tilt can add an additional 10-15° range to the SLR. Average values for the true SLR are between 80-90° measured from horizontal (fig 5).



Fig 5: Assessing hamstring length of the straight leg raise (SLR) monitoring pelvic movement

Hip adductor tightness is determined by passive movement in supine lying. The contralateral leg remains still and the ipsilateral leg must be moved in the horizontal plane only. End range is reached when the pelvis begins to tilt laterally. Average values are 45° from midline (Janda, 1992).

An additional test may be used for the short adductors (not gracilis). The subject starts in crook lying and performs a posterior pelvic tilt. With the feet remaining in position, the knees are rolled out to abduct the hips into a 'frog' position. When an imbalance exists of adductor tightness and abdominal weakness, the subject is unable to maintain the position of the pelvis. The pelvis therefore tilts anteriorly on the affected side, indicated by movement of the anterior superior iliac spine (ASIS) (fig 6).



Fig 6: Measurement of adductor length while assessing pelvic movement

Assessment of Movement Patterns

Muscle imbalance around the trunk and pelvis can change the pattern of movement seen on standard muscle function tests (Lewit, 1991; Janda, 1992). Imbalance in the sagittal plane is characterised by an inability to perform abdominal exercises correctly. A general kinesiological analysis of abdominal exercises is outside the scope of this article, but has been covered elsewhere (Norris, 1993).

For the first movement pattern test, a sit-up action is attempted from a crook-lying position. As this action is performed (fig 7), instead of pure lumbar

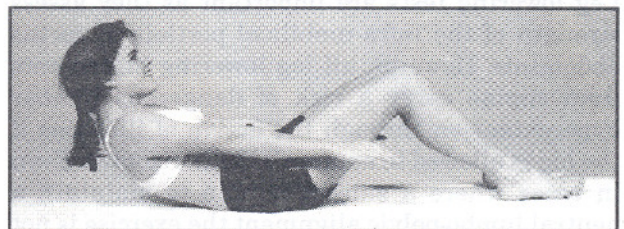


Fig 7: Trunk sit up action from crook lying

flexion preceding hip flexion to enable the subject to sit up, the shortened hip flexors are activated too early and hip flexion dominates the movement with the spine remaining relatively straight. This movement may also be used to assess abdominal muscle strength, and is graded as shown in table 4(1).

Table 4: Grading of trunk muscle strength assessment (Kendall *et al*, 1993; Hoyle and Evans, 1992)

1. Trunk curl

(crook lying, feet flat and unsupported)

- 0 = Unable to raise more than head off table
- 1 = Arms extended towards knees, until scapulae lift from table
- 3 = Arms straight, until lumbar spine lifts from table
- 4 = Arms crossed over chest, until lumbar spine lifts from table
- 5 = Hands behind neck, until lumbar spine lifts from table

2. Leg lowering

(angle between long axis of femur and table, when pelvis begins to tilt — degrees)

- 0 = 90-75
- 1 = 74-60
- 2 = 59-45
- 3 = 44-30
- 4 = 29-15
- 5 = 14-0

Ability to maintain a posterior pelvic tilt while lowering the legs may also be assessed. Initially the supine leg slide is performed (Kendall *et al*, 1993). The starting position is crook lying, and the subject performs a posterior tilt with the pelvis by flattening the back on to the supporting surface. While attempting to hold the flattened lumbar position, one leg is strengthened by sliding the heel distally, maintaining heel contact with the supporting surface to take the weight of the leg. The therapist palpates the ASIS to detect any pelvic movement indicating loss of posterior tilt. As soon as this occurs the test is stopped. If this movement can be performed correctly, both legs may be extended simultaneously, again with the heels remaining on the supporting surface. In strong subjects, leg lowering may be performed as a further test. The starting position is supine lying with the hips flexed to 90° and the knee extended. A posterior pelvic tilt is performed and the ASIS is again palpated. The legs are lowered, while maintaining the flattened lumbar position. When the pelvis begins to tilt the test finishes. For strength assessment the exercise may be scored as shown in table 4(2).

Leg lowering tests are important as they assess strength of the infra-umbilical portion of rectus abdominis. However, all leg lowering movements from supine carry a risk of dangerous lumbar hyperextension through the action of iliopsoas if the leg is allowed to approach the horizontal. Even in cases where a subject is able to maintain a neutral lumbo-pelvic alignment the exercise is not without danger. The compression and shear forces imposed on the lumbar spine, by maximal contraction of the iliopsoas, make this exercise undesirable. For this reason the test must be closely supervised throughout, and must finish when pelvic movement is detected rather than when the back leaves the couch. The bulk of the erector spinae will obscure movement of the spinous processes when viewed from the side in supine

lying. Vertebral movement may therefore occur even though it appears to the untrained eye that the 'back stays flat' on the supporting surface.

Overactivity of the shortened erector spinae in combination with compensatory tightness of the hamstrings can alter the pattern of hip extension. EMG studies in normal subjects have revealed that during prone lying hip extension, the hamstrings contract first, followed by the gluteals and then the contralateral erector spinae and finally the ipsilateral erector spinae (Lewit, 1991). Tightness of the hip flexors in PCS may inhibit the gluteus maximus (pseudoparesis). In this case, during prone hip extension the contraction of the gluteus maximus may not be detected, but the total strength of hip extension may remain the same to manual testing, due to contraction of the hamstrings. Flexing the knee will reduce the mechanical advantage of the hamstrings *via* the length-tension relationship (Bray *et al*, 1986) and a poor ability to extend the hip is then apparent in contrast to the contralateral limb. In severe cases of PCS the erector spinae are seen to contract powerfully at the initiation of hip extension. This will tilt the pelvis anteriorly and pre-stretch the hamstrings, enabling them to contract more

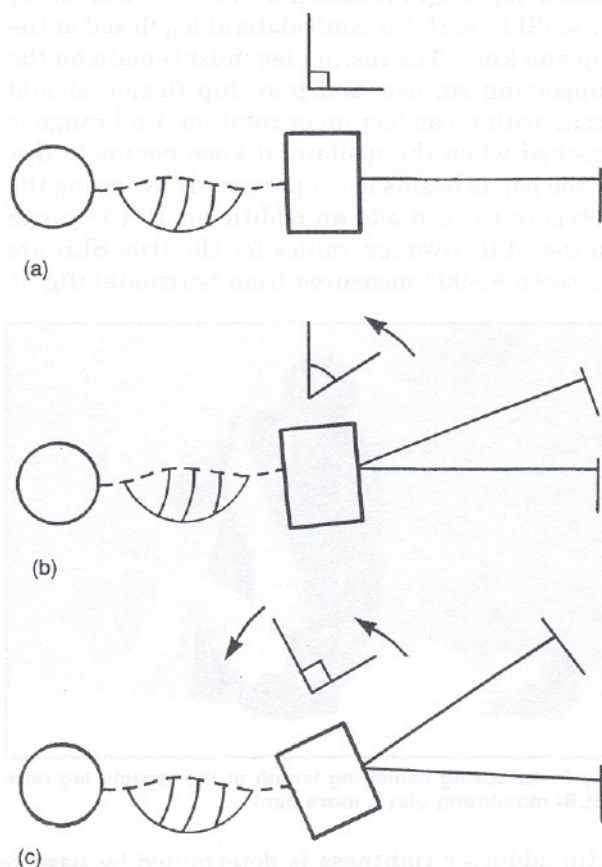


Fig 8: Assessing active hip extension

- (a) Resting position — neutral position of pelvis
- (b) Correct leg extension — pelvis remains neutral. Angle between femur and pelvis reduces
- (c) False leg extension — pelvis tilts anteriorly, increasing the lumbar lordosis. Femur remains at 90° to pelvis

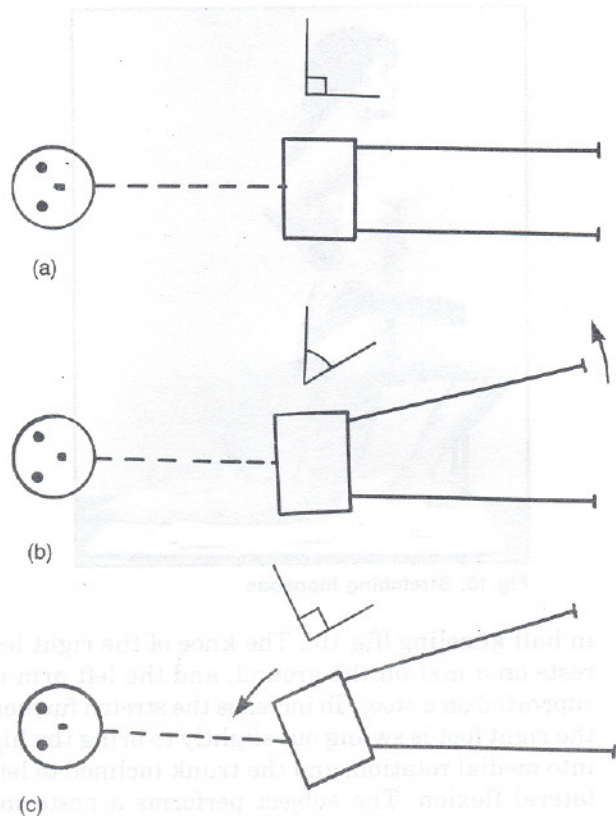


Fig 9: Assessing active hip abduction

- (a) Starting position — pelvis neutral, legs resting
 (b) True abduction — pelvis neutral. Angle between femur and pelvis reduces
 (c) False abduction — pelvis tilts laterally. Angle between femur and pelvis remains unchanged

powerfully. In addition, the anterior tilt of the pelvis will cause the appearance of hip extension, although the relationship between the pelvis and femur of the moving leg remains unchanged (fig 8). Rotation of the upper lumbar and lower thoracic spine may also occur towards the contralateral side. This occurs when the gluteus maximus fails to stabilise the pelvis (Bourdillion *et al*, 1992).

During gait the decrement in hip extension power cannot be met completely by substitution of the hamstrings. Further hip extension is achieved by anteriorly tilting the pelvis and hyperextending the lumbar spine. The hyperextension action places an increased stress on the lumbar spine and causes an exaggerated pelvic sway or 'duck waddle'.

A further imbalance pattern occurs between tight hip adductors, tensor fascia lata, and quadratus lumborum and inhibition of the gluteus medius and minimus. This is seen especially in the sway back posture where one leg is favoured in relaxed standing. The imbalance pattern is characterised by poor pelvic stability in the frontal plane seen on single leg standing and an altered movement pattern to hip abduction in side lying. From a side lying position the subject is instructed to abduct the hip actively. With true abduction, activation

of the gluteus medius and minimus and tensor fascia lata is equal. Where imbalance occurs, a pseudoparesis of the two glutei can occur through tightness of the adductors. In this case gluteus medius and minimus contract too late in the movement sequence or not at all. The shortened tensor fascia lata is activated too soon, and the weakness of abduction causes the subject to move his or her leg into partial hip flexion and lateral rotation as a 'trick' movement to complete the action. The quadratus lumborum (commonly shortened) may be hyperactive to create a substitution movement. False abduction is caused as the quadratus contracts and tilts the pelvis laterally (fig 9). The initial appearance is of abduction, but on closer inspection the relationship between the pelvis and the ipsilateral leg remains unchanged. Instead, the pelvis has moved on the stationary contralateral leg.

Assessing Holding Capacity of Stability Synergists

The ability of a stability synergist to maintain an isometric contraction at low load over a period of time is vital to its antigravity function (Richardson, 1992). This may be assessed by using the classic muscle test positions and asking the subject to maintain a contraction in inner range (Richardson and Sims, 1991). The important factor in the assessment is the length of time a static hold can be maintained without jerky (phasic) movements occurring.

Iliopsoas is assessed in sitting. The patient flexes the hip while maintaining 90° knee flexion so that the foot is lifted clear of the ground. Gluteus maximus is assessed in prone lying with the knee flexed to 90°. The hip is lifted to inner range extension and held. Gluteus medius is tested in side lying. The action is combined hip abduction, with slight extension and lateral rotation to emphasise the posterior fibres of the muscle. Assessment of the holding capacity of the stability synergists of the trunk using pressure biofeedback is covered in the following article.

Restoration of Muscle Balance

The imbalance between shortened and lengthened muscles found during assessment dictates that shortened muscles should be stretched, while lengthened muscles are shortened. Only when the muscle imbalance has been corrected should general strengthening be considered. Lengthened muscles are shortened by exercising them in their inner range (shortened) position. Shortened muscles are stretched using static and PNF stretching procedures. Restoration of general muscle strength in the hip and lumbar spine is covered elsewhere (see Norris, 1993b).

Shortening lengthened muscles (see stability synergist above) may be achieved by contracting the muscle in inner range, or splinting it in this position. Slow twitch muscle fibre function is then retrained by using low loads (20-30% MVC) and the contraction is held for ten seconds. The position chosen is typically that used for manual muscle testing (MMT) and the reader is referred to Kendall *et al* (1993), Janda (1983), Lacote *et al* (1987) and Clarkson and Gilewich (1989) for a description of these tests.

To lengthen muscle, static stretching is used initially, holding the position for ten seconds (Borms *et al*, 1987). When this can be achieved, PNF stretching may be used. Contract-relax (CR) stretching or post-isometric relaxation (PIR) requires the subject first to contract the muscle to be stretched and hold the contraction for 10-20 seconds (Etnyre and Lee, 1987). During this period the golgi tendon organs will register the tension build up and cause autogenic inhibition, allowing an increased range of motion to be gained. Additional range can be obtained by using contract-relax-agonist-contract (CRAC) procedures. Here, after the muscle being treated has contracted and been allowed to relax, the opposing muscle is contracted by pulling further into the stretched position and causing reciprocal innervation. This has the added benefit of strengthening the muscle group which controls the range of motion, but can be difficult to practise at home.

As the lengthened muscle is often the antagonist to the shortened one, contracting the shortened muscle in inner range will place a stretch on its lengthened antagonist. Because the lengthened muscle has increased its number of sarcomeres, however, it will not be able to pull the joint into full inner range when it contracts. The passive range of motion at such a joint will therefore be greater than the active range. When muscle balance has been restored, the passive and active ranges of joints with uni-articular muscles can be expected to be more equal.

The following stretching exercises are illustrated for the right hand side of the body in each case.

Iliopsoas

1. The iliopsoas may be stretched initially in supine by performing the Thomas test itself. As a static stretch the testing position is simply held. As PIR technique the right leg is first raised 2 cm from the couch by active hip flexion and held. The leg is then relaxed, and further range of movement is achieved. This position however is not functional as stability of the pelvis is largely supplied by the weight of the dependant limb.

2. A more effective static stretch may be achieved



Fig 10: Stretching iliopsoas

in half kneeling (fig 10). The knee of the right leg rests on a mat on the ground, and the left arm is supported on a stool. To increase the stretch further, the right foot is swung out slightly to bring the hip into medial rotation, and the trunk inclined to left lateral flexion. The subject performs a posterior pelvic tilt and maintains this position throughout the stretch by contraction of the abdominals and gluteals. The pelvic tilt in itself will stretch the proximal insertion of the iliopsoas and may be sufficient as a starting exercise in very tight subjects. From this position, the action is to lunge forward while applying pressure over the buttock with the right hand. The rectus femoris may be stretched further in this position by pulling the knee into flexion. Allowing an anterior pelvic tilt is a common error which gives the appearance of increased hip extension range. In reality hip extension has remained unchanged, but lumbar extension has simply increased.

Rectus Femoris

1. The rectus femoris is stretched in the Thomas test position using PNF by first contracting the quadriceps to extend the right knee and then relaxing to allow the leg to rest further into flexion. Finally, contraction of the hamstrings may be used to increase knee flexion still further.

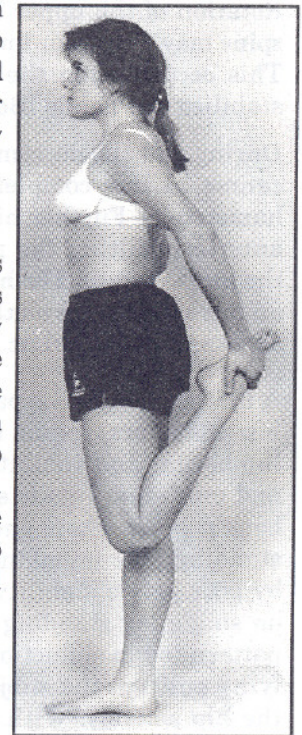


Fig 11: Rectus femoris stretching

2. In support standing the stretch may be combined with pelvic control. The subject performs a posterior pelvic tilt and holds this position throughout the stretch. The right knee is flexed and the leg pulled back into hip extension. No hip abduction or pelvic movement should occur (fig 11).

Adductors

The adductors may be stretched in sitting or lying. The gracilis will be stretched only if the knee is extended.

1. The subject starts in crook sitting against a wall to support the spine. The initial action is an anterior tilt of the pelvis, and this position is held throughout the exercise. The soles of the feet are held together and the knees pressed to the ground. PNF techniques may be used by pressing up with the knees against the hands and then pulling down actively with the abductors (fig 12).



Fig 12: Adductor stretching

2. The adductors (including gracilis) may be stretched in lying with the hips flexed to 90° and abducted, and the knees extended. This is better performed against a wall for support. PNF stretching is performed by adducting the legs to close them and then abducting to open them further (fig 13).

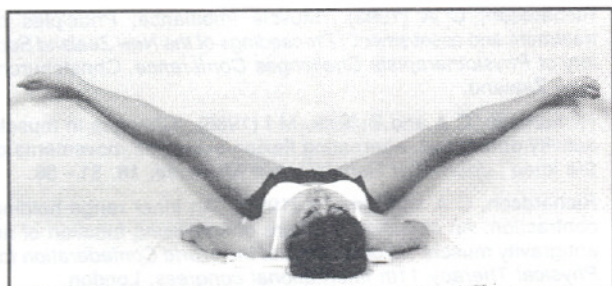


Fig 13: Adductor stretching including gracilis

Quadratus Lumborum

The subject starts in left side lying, over a rolled pillow. The right knee must clear the end of the couch. The stretch is applied by reaching the right arm overhead, and allowing the right leg to lower into adduction (fig 14).

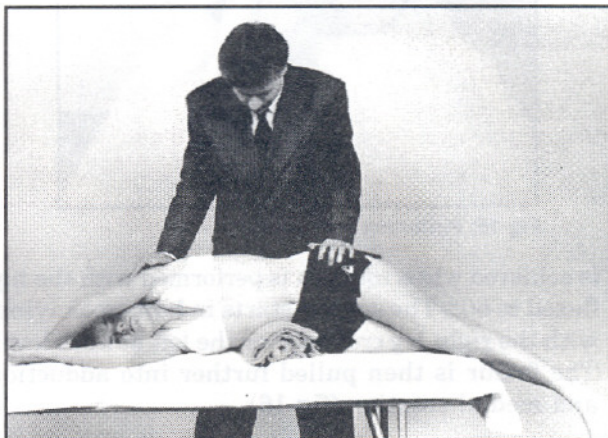


Fig 14: Stretching quadratus lumborum

Hip Rotators

The subject begins in prone lying, with the knees flexed to 90°, and a light sandbag over each ankle. While maintaining 90° knee flexion, the ankles are lowered in an arc to rotate the hip. When the ankles move outwards (medial rotation of the hip) the lateral rotators are stretched. Allowing the ankles to fall inwards into lateral rotation will stretch the medial rotators of the hip. A neutral position of the pelvis must be maintained throughout the movement (fig 15).

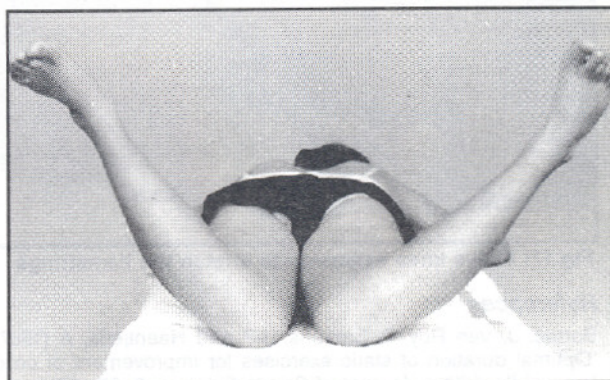


Fig 15: Hip rotator stretching

Piriformis

Tightness of the piriformis has been implicated in sacroiliac dysfunction (Bourdillion *et al*, 1992). Although tightness of the muscle may be revealed by movement limitation and pain, palpation of the tense muscle belly over the greater sciatic notch is a more accurate measure (Jull and Janda, 1987). The line of the piriformis means that it will only be partially stretched by rotation movements with the hip in the neutral position. A greater stretch

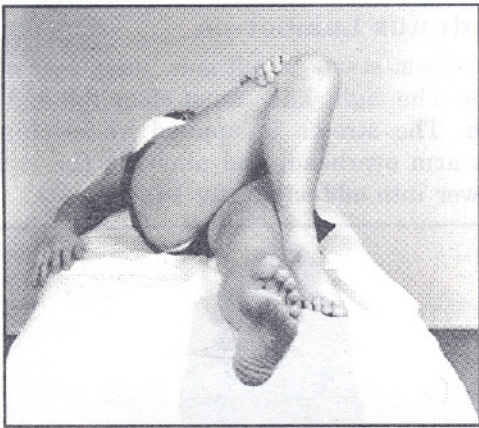


Fig 16: Piriformis stretching

is achieved when rotation is performed with the hip flexed to 60°. The subject starts in half crook lying, with the right leg crossed over the left at knee level. The femur is then pulled further into adduction and medial rotation (fig 16).

Hamstrings

The subject begins in supine lying, with the right hip and knee flexed to 90°, gripping the left leg behind the knee, and actively extending the right leg, attempting to press the heel towards the ceiling. A lumbar roll used to maintain the lordosis and tilt the pelvis anteriorly will increase the stretch (fig 17).

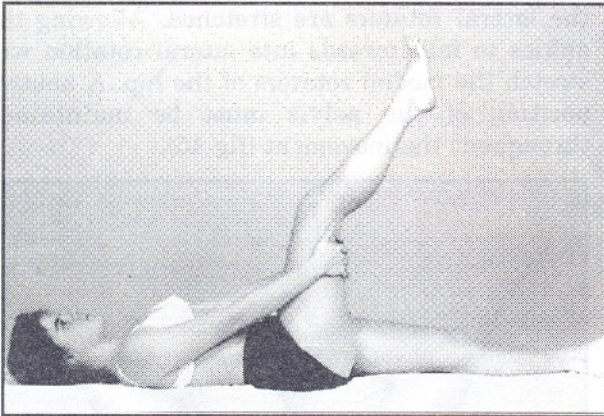


Fig 17: Active knee extension to stretch the hamstrings

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