

# Malalignment Syndrome

The malalignment syndrome is characterized by the following features:

- ◆ Distortion of the pelvic ring
- ◆ Associated changes in the alignment of the axial and appendicular skeleton, so that there appears to be a reorientation of the body from head to foot
- ◆ Compensatory changes in the soft tissue structures
- ◆ Occasionally also visceral involvement, affecting the genitourinary, gastrointestinal and reproductive systems.

Diagnosis rests on the findings of:

- ◆ asymmetrical alignment of the bones of the pelvis, trunk and extremities
- ◆ compensatory curvatures of the spine, with or without associated malrotation of one or more vertebrae
- ◆ asymmetrical ranges of motion of the head and neck, trunk, pelvis and joints of the upper and lower extremities
- ◆ asymmetrical tension in the muscles, tendons and ligaments
- ◆ asymmetrical muscle bulk and strength
- ◆ an apparent (functional) leg length difference
- ◆ an asymmetrical weight-bearing pattern.

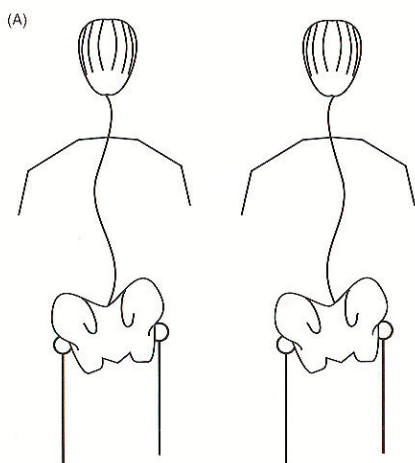
## Effect of malalignment on the spine

The pelvic obliquity attributable to rotational malalignment results in compensatory curves of the spine or the accentuation of any pre-existing curves (the so-called 'normal' or 'intrinsic' curves). If the spine did not accommodate to the obliquity, the head would end up off center, disturbing the visual and balancing mechanisms. The spine cannot accommodate without a rotation of the vertebrae in the thoracic and lumbar segments.

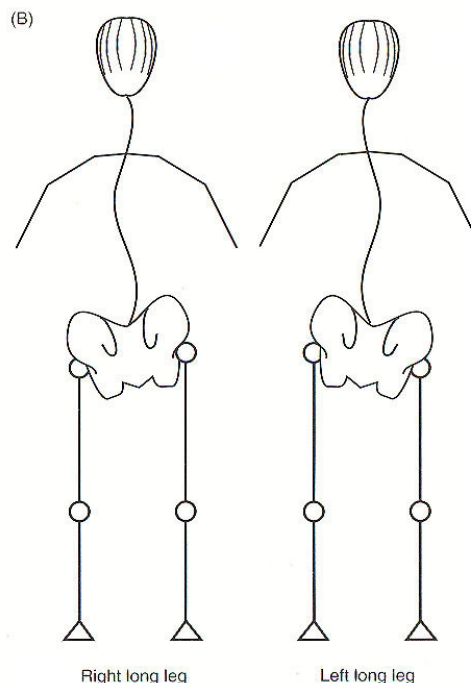
If the cervical spine simply continued in the trajectory of the thoracic curve, the patient would be walking about with the head and neck half-cocked, leaning towards the side of the thoracic concavity. Among other things, this would upset the balancing mechanism, which is dependent on visual and vestibular input and also, in large part, on proprioceptive signals arising from the muscles and joints in the neck region. The brain could have difficulty dealing with sensory input derived if the head and neck were set at an angle.

There is therefore a further reversal in the curvature of the spine in order that the head will hopefully end up straight and in the midline. Reversal occurring in the upper thoracic region creates another stress point and may account for reports of interscapular and/ or upper back discomfort.

## Typical patterns of scoliosis (standing)



(A) Patterns seen with rotational malalignment and associated pelvic obliquity (up on the right side in the majority).



(B) Scoliotic curves commonly seen with the right and left anatomical leg length difference.

## Biomechanical effects of the curves

### *The Lumbar segment of the spine*

**Clinical correlation.** The overall biomechanical effects of a lumbar convexity superimposed by malalignment, and possible clinical correlations, include the following.

- ◆ **Decreased movement, or even locking, of the lumbar segment.** With time, this may exceed the safety role of the locking that occurs physiologically with normal side flexion of the trunk.
- ◆ **Narrowing of the facet joint space on the concave side.**
- ◆ **Narrowing of the disc and compression of the lateral vertebral margins on the side of the concavity.** This constitutes a stress on both the disc and the vertebrae, with displacement of the nucleus pulposus and bulging of the annulus fibrosus toward the side of the convexity.
- ◆ **Widening of the joint margin on the side of the convexity.** This widening, combined with the bulging of the annulus, puts the annular attachments to the vertebral margins under increased stress on the convex side.
- ◆ **Torsion of the annulus in a clockwise direction.** This puts the oblique annular fibers and their nerve supply under increased stretch.

- ◆ **Narrowing of the disc anteriorly.** This results from the forwards flexion of the lumbar vertebrae. There is an associated increase in pressure, forcing the disc contents posteriorly, which contributes to any posterior or lateral bulging of the disc and also increases the tension in the posterior longitudinal ligament.

The question is whether these individual stresses alone, or in combination, can initiate and/ or accelerate the degeneration of the lumbar spine segment, including the deterioration of the annulus, with eventual disc protrusion. Certainly, the combination of axial rotation and simultaneous side flexion has been identified as the worst form of distortion to which the disc can be subjected in terms of precipitating the degenerative changes that eventually lead to disc protrusion.

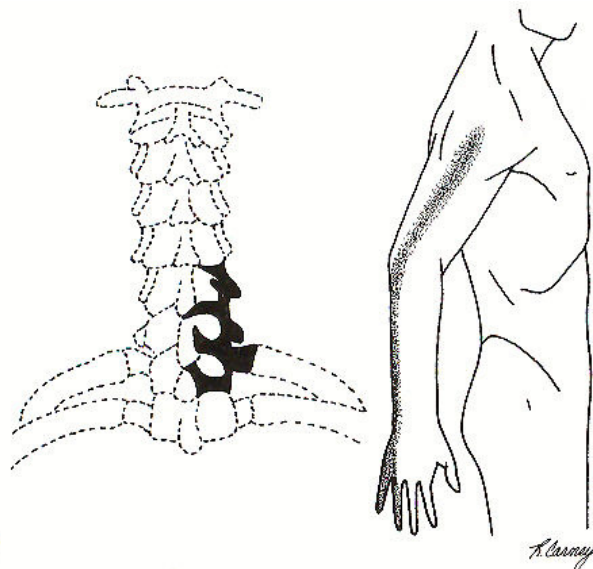
### *The cervical segment of the spine*

A number of patients present with neck pain in association with pelvic malalignment. Sometimes there is a localizable increase in tension and tenderness in neck muscles, more commonly on the right side (e.g. right upper trapezius). The curvature of the cervical segment is usually opposite in direction to that of the thoracic segment. As noted above, the point of reversal is sometimes as far down as T4 or T5. At the level of the reversal, wherever that may be, there is an associated rotation and side flexion of the adjoining vertebrae in opposite directions. Together, these factors create another site of increased stress, often tender to palpation even though the patient may not otherwise be aware of pain from this site.

The malalignment of the pelvis and spine results in an asymmetry of tension in all the skeletal muscles. In the neck, there is more consistently evidence of increased tension in the right upper trapezius.

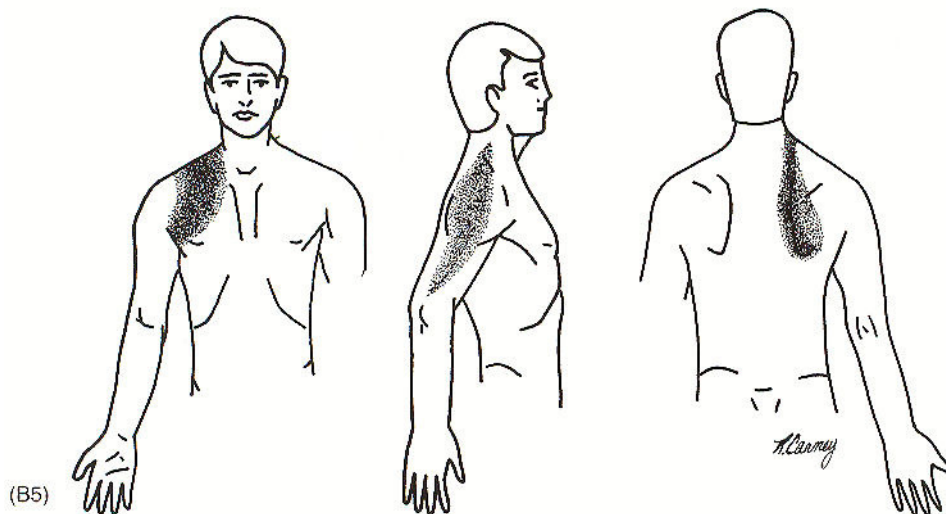
**Clinical correlation.** Patients with neck pain related to malalignment of the pelvis and spine sometimes have associated symptoms in the upper extremities. These include dysaesthesias and paraesthesias, which disappear with realignment only to recur as malalignment recurs. Possible causes for these arm symptoms include the following.

- ◆ **Referral from structures in the neck that are being irritated by the malalignment.** Curve reversal at the cervicothoracic junction, for example, indicates that there is a contrary rotation of C7 and T1, putting increased stress on the intervertebral, supraspinous and interspinous ligaments joining the two vertebrae, and the ligaments attaching to the C7 transverse processes. These ligaments can refer pain to the medial aspect of the forearm and the fourth and fifth fingers, in effect mimicking a C8 root problem and even angina. (B4)



Rotation in the mid-cervical region can cause irritation of the C5 and/ or C6 nerve roots, resulting in symptoms that may suggest a C5 or C6 radiculopathy. Evidence for root compression is usually lacking on neurological, electrodiagnostic or other investigations. The irritation of ligaments at the C5/C6 level can cause referred pain to the sclerotome region on the lateral aspect of the elbow, the symptoms often leading to futile treatments for a problem erroneously diagnosed as 'lateral' epicondylitis. Referral from the C8/T1 level can similarly mimic 'medial' epicondylitis.

The upper cervical and occipital region can refer to various areas of the skull. Trigger points that develop in the neck muscles can refer to the shoulder girdle, the anterior and posterior chest regions and the upper extremities. Interestingly, these trigger point referral patterns overlap with sclerotomal referral patterns originating from the ligaments attaching to the C7 transverse processes. (B5)



- ◆ **Irritation of nerve tracts and vascular structures.** The cervical roots and brachial plexus exit the neck region running through the cervical paravertebral muscles and then in between the anterior and middle scalene muscles, together with the subclavian artery, whereas the subclavian vein runs anteriorly to the anterior scalene. The vessels and nerves then proceed through the thoracic outlet, formed by the clavicle and first rib. A chronic increase in tension in the scalene and other surrounding muscles can narrow the space available to the exiting neurovascular bundle, both between the scalenes and in the thoracic outlet region, sometimes to the point of exerting direct pressure on these structures.

A rotation of the clavicle and the first rib caused by the malalignment can result in a further narrowing of the thoracic outlet. Irritation of the nerve fibers as a result of increased tension or direct pressure on the nerve tracts and/ or a compromise of their blood supply can cause symptoms and clinical findings suggestive of a nerve root, brachial plexus or peripheral nerve lesion, or of a thoracic outlet syndrome. Adson's maneuver may provoke paraesthesia, occasionally with an associated diminution or obliteration of the radial pulse. In the absence of a neurological deficit on examination, electrodiagnostic studies are usually normal.

The symptoms may be abolished by correction of the malalignment, with particular attention to any coexisting malrotation of the cervical and upper thoracic vertebrae, the clavicle and the upper ribs. Realignment may help simply by increasing the space available for the neurovascular bundle by:

- relaxing the surrounding muscles and reestablishing the normal spatial relationship between the vertebrae, clavicle and first rib
- decreasing tension, and hence irritability, on nerves within ligaments and also on the autonomic fibers in this area.

## **ASYMMETRY OF THE THORAX, SHOULDER GIRDLES AND ARMS**

Side flexion of the trunk will normally have the following effects.

- ◆ Brings the ribs together on the concave side
- ◆ Causes some rotation of each pair of ribs in opposite directions – anteriorly on the concave side, posteriorly on the convex side – a movement that appears to be determined by the fact that:
  - after the motion of the ribs on the concave side has stopped, the thoracic vertebrae continue to side flex slightly into the concave side
  - this continued motion of the vertebrae causes the ribs on the concave side to glide upwards, and the ribs on the convex side to glide downwards, at the costotransverse joint
  - the direction of this movement of the ribs is guided by the orientation of the costotransverse joint surfaces, translating into anterior rotation on the concave and posterior on the convex side.

There is also an element of rotation of the vertebrae in the transverse plane. Whether this is directed into the convexity or the concavity seemingly depends on whether the initiating motion was either a pure side flexion or a trunk rotation. Vertebral rotation in the transverse plane automatically rotates each set of attaching ribs in the same plane, posteriorly on one side and anteriorly on the other. The malrotation of a vertebra could result in similar effects on the ribs but in an exaggerated way. For example, left rotation and side flexion of T5 can result in a rotational stress on the fifth ribs.

A common presentation in standing is with a counterclockwise rotation of the pelvis in the transverse plane (right side forward) and a thoracic curve convex to left. The most frequent associated findings on examination are as follows:

- ◆ There is clockwise rotation of the thorax in the transverse plane, bringing the left shoulder forwards as if to compensate for the pelvis being forward on the right side. Simultaneous counterclockwise rotation of the thorax is, however, almost as common and results in both the pelvis and the shoulder being rotated forwards on the right.
- ◆ The right shoulder girdle is retracted and depressed, the left protracted and elevated.
- ◆ The right scapula is rotated clockwise, sometimes to the point that the medial border ‘wings’ and studies are initiated for suspected weakness of mid-trapezius, the rhomboids or serratus anterior and a possible long thoracic nerve injury.
- ◆ Depression of the right shoulder and clockwise rotation of the right scapula reorients the glenoid fossa downwards and posteriorly, whereas, on the elevated left side, the fossa ends up pointing more upwards and anteriorly.

- Reorientation of the thorax and shoulder girdles and asymmetries of muscle tension alter the ranges of motion possible at the shoulder joints. The typical pattern includes a decrease in right internal, left external rotation and a decrease in left extension.
- ◆ Malalignment can also result in an obvious asymmetry of some other upper extremity ranges of motion. For example, a typical finding is a 5-15 degree limitation of left forearm pronation and right supination.
- ◆ Malalignment usually results in an asymmetry of strength in the shoulder girdle and upper extremity muscles. The detection of weakness is dependent on the position of examination and may not be as easily or as consistently apparent as the asymmetrical weakness noted in the lower extremities. Differences are usually more obvious in the proximal muscles, especially the arm flexors and particularly the anterior deltoid, and can disappear dramatically with realignment.

**Clinical correlation.** The asymmetry of thoracic and shoulder girdle alignment, and of the strength and tension of the muscles in this area, increases the stress on the shoulder joint and rotator cuff complex bilaterally. This stress increases the likelihood of developing shoulder pain and may predispose to impingement, acute or chronic sprain, and other injury to this region.

These mechanisms may also play a role in the development of a complicating supraspinatus tendonitis, impingement, calcific tendonitis and subacromial bursitis.

## ASYMMETRY OF LOWER EXTREMITY ORIENTATION

Most patients who are in alignment have their lower extremities in some external rotation, both feet pointing outwards some 10-15 degrees relative to the middle. A small number have their legs in 'neutral', the feet pointing straight forwards, and some are 'pigeon-toed', both feet pointing inwards. Barring the effect of previous injuries, foot orientation relative to the midline is usually symmetrical with all three presentations.

Rotational malalignment, on the other hand, results in an asymmetrical orientation of the lower extremities: one leg undergoes external and the other internal rotation.

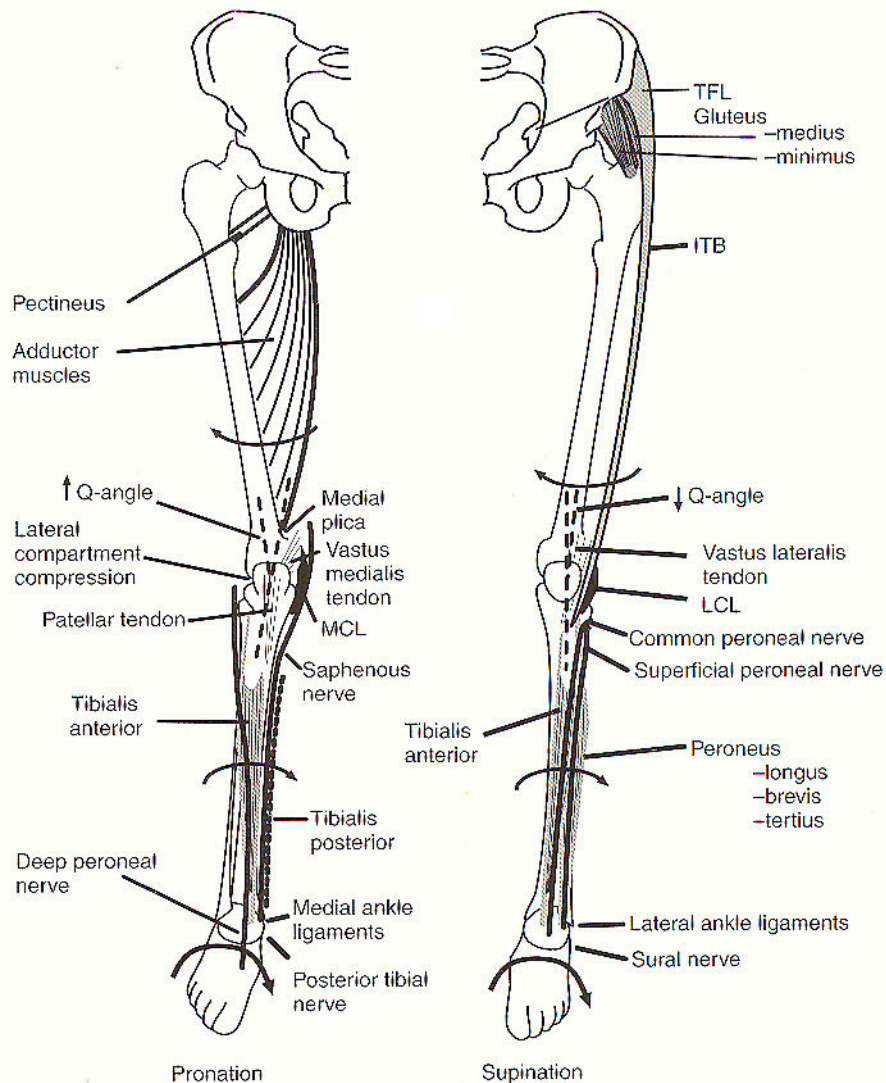
**Clinical correlation.** The shift in weight-bearing that occurs with malalignment results in an asymmetry of forces in the lower extremities that predisposes to the injuries typically associated with pronation and supination.

*On the side of external rotation and pronation*

### **Increased tension in structures on the medial aspect of the leg:**

- ◆ groin pain and/ or medial thigh pain (irritation or sprain of the pectineus / adductor origin muscle mass or insertions)
- ◆ medial collateral ligament and medial plica
- ◆ snapping of the medial plica and vastus medialis tendon across the medial condyle
- ◆ medial shin splints from irritation and periosteal inflammation along the tibialis posterior origin
- ◆ medial ankle ligaments (especially anterior tibiotalar).

*Structures put under stress by a right pronation, left supination shift with malalignment.*



**Peripheral nerve involvement:**

- ◆ traction injury to the posterior tibial, saphenous and distal (medial) deep peroneal nerves
- ◆ compression injury of the sural nerve.

**Increased valgus tendency at the knee, with:**

- ◆ increased pressure in the lateral joint compartment
- ◆ increased Q-angle and lateral tracking of the patella, pressure in the patellofemoral compartment and tension in the patellar tendon
- ◆ irritation of the saphenous nerve.

**Increased weight-bearing on the medial aspect of the foot:**

- ◆ aggravation of problems relating to a hallux valgus, rigidus and limitus
- ◆ acceleration of first metatarsophalangeal bunion formation and degeneration
- ◆ sesamoiditis

- ◆ plantar fasciitis on the basis of excessive traction attributable to calcaneus eversion and collapse of the medial longitudinal arch
- ◆ posterior tarsal tunnel syndrome, with irritation or compression of the posterior tibial nerve
- ◆ in the case of bilateral Morton's toes, a unilateral aggravation of stress on the second and third metatarsal heads with callus formation, tenderness and/ or outright pain (metatarsalgia) or even stress fracture.

**Achilles tendonitis on the basis of excessive traction, attributable to:**

- ◆ the separation of origin and insertion that occurs because of the calcaneus collapsing into valgus
- ◆ the increased ankle dorsiflexion usually possible on this side.

*On the side of internal rotation and supination*

**Increased tension in the lateral structures of the leg:**

- ◆ sprain of the hip abductors (gluteus medius / minimus) and the TFL/ITB complex
- ◆ bursitis (greater trochanter and lateral femoral condyle)
- ◆ lateral shin splints (tibialis anterior and/ or peroneal muscle group tendonitis or sprain)
- ◆ lateral ankle ligaments.

**Peripheral nerve involvement:**

- ◆ traction injury to the common and superficial peroneal nerves, the sural nerve and the lateral femoral cutaneous nerve
- ◆ compression injury of the posterior tibial nerve.

**Tendency to varum at the knee, with:**

- ◆ increased pressure in the medial joint compartment
- ◆ traction on the vastus lateralis insertion and lateral collateral ligament
- ◆ snapping of the vastus lateralis across the lateral femoral condyle.

**Increased rigidity of the foot and ankle:**

- ◆ an impaired ability to dissipate ground forces, predisposing to the development of plantar fasciitis, Achilles tendonitis and stress fractures.

**Increased weight-bearing on the lateral aspect of the foot:**

- ◆ painful callus formation, fourth and fifth metatarsalgia, and metatarsal stress fractures.

**ASYMMETRY OF MUSCLE TENSION**

Muscles are meant to contract and relax. Relaxation results in an increase in blood flow, allowing for the optimal clearance of waste and the delivery of oxygen and nutrients. Contraction results in a decrease in blood flow and an impaired clearance of waste. A contraction of only 60% of maximum has been shown to stop blood flow into and out of the muscle completely.



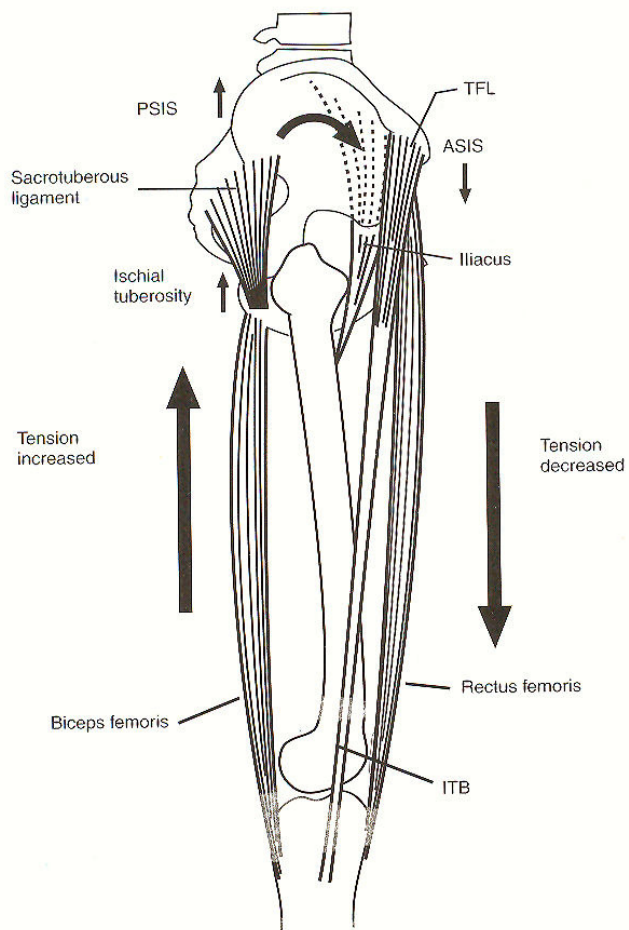
A constant increase in muscle tension means that the muscle is always to some extent working; there is a continuous increase in energy consumption and production of waste occurring at a time of diminished blood flow. At the same time, a constant traction force is being exerted on the muscle's origin and insertion. Given this persistent increase in tension, the muscle bulk proper and/ or its points of attachment will eventually become tender to palpation or outright painful. The term 'chronic tension myalgia' seems appropriate because the pain itself is myofascial in origin, involving the muscle itself, the neurovascular bundle, the enveloping fascia and the fibro-osseous junctions.

Whatmore & Kohli have, however, postulated that the chronic contraction eventually fatigues the physiological mechanisms that sustain the contraction. When the energy reserves of the individual fibers drop below a critical level, 'fatigue spasm' ensues: the fibers remain involuntarily shortened. Persistent fatigue spasm can lead to a fixed shortening of muscle fibers that is maintained by 'physiochemical processes' within the fibers. Muscle fibers atrophy at the same time that the fibrous content of the muscle increases. This can sometimes be appreciated as tender, localized areas of crepitus on palpation. Once the condition has reached this stage it becomes much harder, sometimes impossible, to reverse.

### Malalignment-related increase in muscle tension

In the presence of malalignment, a chronic increase in muscle tension can result for four main reasons.

- ◆ The malalignment has increased the distance between the muscle's origin and insertion
- ◆ The malalignment per se is associated with an automatic increase in tension or 'facilitation' of specific muscles
- ◆ The increase in muscle tension is an attempt to splint
  - an area that is painful
  - an area that is unstable

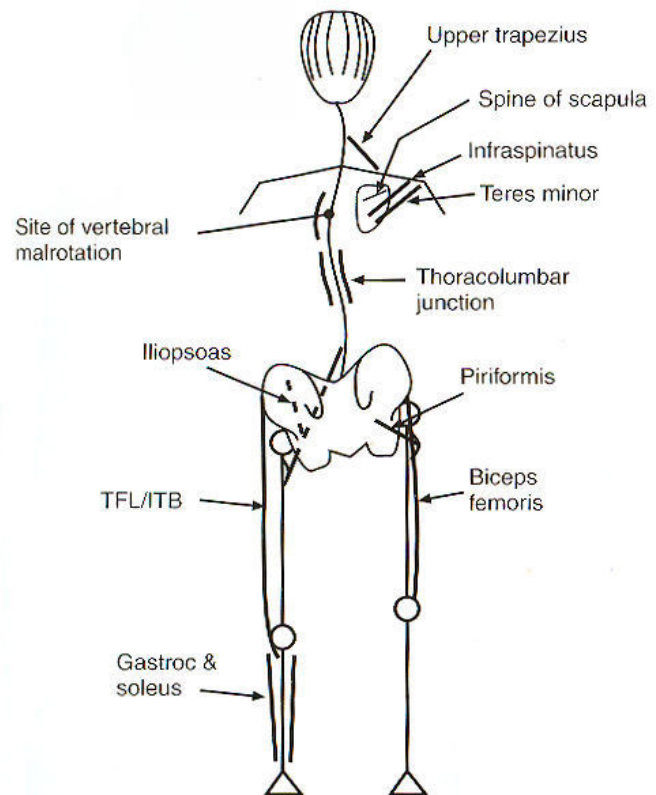


*Change in tension resulting from the shift of the origin towards or away from the insertion with right innominate anterior rotation (e.g. tension increased in rectus femoris and decreased in iliopsoas). The reverse changes occur with right posterior rotation. PSIS, posterior superior iliac spine; ASIS, anterior superior iliac spine; TFL, tensor fascia lata; ITB, iliotibial band.*

The following are some possible mechanisms to consider. First, malalignment results in an asymmetry of proprioceptive signals arising from the joints. However, as with muscle weakness, the muscles showing the increase in tension tend to be consistently the same regardless of the presentation of malalignment. For example, the increase in tension consistently involves the left hip abductors and TFL/ITB complex, regardless of whether the malalignment is in the form of an upslip or anterior rotation, has associated SI joint 'locking' or is on the right or left side. Asymmetry of proprioceptive signals, therefore, does not seem to offer a plausible explanation for this phenomenon.

Second, the above findings argue more for a cause at the spinal segmental or cortical level. The increased tension may reflect segmental muscle 'facilitation' or 'inhibition'. The pelvic malalignment could cause an increase or decrease in excitatory or inhibitory signals to muscles; alternatively, the malalignment may itself have evolved as a result of such signals to the muscles arising from some other cause.

*Typical sites of increased muscle/tendon tension and tenderness resulting with malalignment. The drawing also indicates the typical lateralization; if the structure is involved bilaterally, the one indicated here is usually affected more severely. TFL/ITB, tensor fascia lata/iliotibial band.*



Third, some of the central effects of articular mechanoreceptor stimulation pointed out by Wyke may be operative. These include the nociceptor afferent activity arising from the type IV receptor system within the joint capsule and the fibers of the intrinsic joint and spinal ligaments. A pain-suppressive effect normally occurs with 'activation of the apical spinal interneurons', producing 'presynaptic inhibition of this nociceptor afferent activity'. Perhaps with the distortion of joint surfaces, ligaments and capsules associated with malalignment, there is an excessive stimulation of type IV receptors to the point at which activation of interneurons becomes inadequate, resulting in a failure of pain suppression at a segmental level. The increased tension in the paravertebral and more distal muscles may therefore reflect a problem at the spinal segmental level.

Finally, the malalignment, whatever its presentation, may induce rather non-specific signals related, for example, to stretching or irritation of the dura. These signals in turn have a general effect of stimulating or suppressing cortical motor signals to certain motor spindles, and inducing facilitation or inhibition, respectively.

### *Tension increased in an attempt to splint a painful area*

The muscles in the vicinity of a painful area usually show an increase in tension. This may occur as a reaction to irritation of the nociceptive fibers. It may also reflect a reflex attempt to splint the painful area in order to prevent the aggravation that would otherwise occur with movement. Malalignment automatically stresses a number of structures, in particular the joints of the spine and pelvis. These sites can eventually become a source of irritation or pain that is aggravated by movement or further stress imposed by activity. It is not unusual to find increased tension (and tenderness) in the muscles capable of decreasing or preventing the movement of these painful areas. There is, for example, often splinting of the paravertebral muscles immediately adjacent to a malrotated vertebra and at sites of curve reversal, particularly the thoracolumbar junction.

### *Tension increased in an attempt to stabilize an area*

Malalignment is frequently associated with joint instability for various reasons. Laxity of the ligaments, which allows for a recurrent malrotation of one or more vertebrae, results in a recurrent or chronic increase in tension in the paravertebrals and any other muscles that span that segment. The instability of SI joints that can occur with sacral and innominate rotation and upslips typically increases tension in the prime muscles that can stabilize the joint by wedging the sacrum against one or both innominates: piriformis by pulling the sacrum backwards relative to an innominate, iliacus by pulling the innominate forwards against the anteriorly widening sacrum.

In summary, in the presence of malalignment, one sees an increase in tension in certain muscles. This may be in response to pain or instability, a mechanical increase in the distance between origin and insertion, or some other mechanism, segmental or cortical, that affects the muscle spindle setting and results in facilitation.

As long as the malalignment is present, the muscles involved are unlikely to respond to stretching attempts or will do so only temporarily. With time, these muscles, their tendons and points of attachment can become tender to palpation or overtly painful. The myofascial pain that results may remain localized, have a referred component or both. A persistent increase in tension secondary to malalignment increases the risk of sprain or strain of the affected muscles with patient activity. Conversely, realignment may greatly benefit the recovery of those who have suffered a sprain or strain, simply by removing that component of the increase in tension and pain which is attributable to the malalignment.

### **The right piriformis muscle**

Fifty-eight percent of the 96 patients presenting with malalignment in the Schamberger study had increased tone in the piriformis; the right was six times more likely to be affected in isolation and even more likely to be tender to palpation than the left. Those with one of the 'alternate' presentations of rotational malalignment were noted to have external rotation of the right lower extremity, the majority also showing torsion of the sacrum around an oblique axis, almost as often to the right as to the left.

Both external rotation and torsion around the left oblique axis would bring the piriformis origin (from the anterior aspect of the sacrum) closer to its insertion (into the upper, posterior aspect of the greater trochanter) and should therefore relax this muscle. The increased involvement of right piriformis with

malalignment therefore appears more likely to be a reflection of the facilitation of that muscle, an attempt to splint an unstable or painful right SI joint or a combination of these.

The separation of the piriformis origin and insertion could be expected as a more probable cause for the involvement of this muscle on the left side. The commonly noted internal rotation of the left lower extremity, combined with sacral torsion around the left oblique axis, would certainly increase the distance between its origin and insertion. However, the patients who presented with this combination failed to show any correlation to whether the left or right piriformis was involved. Study results relating to sacral torsion would also argue against a separation of origin and insertion being the cause of any increase in tension on the left side. The less frequently noted involvement of the left piriformis is probably also more likely to be attributable to facilitation, an attempt to stabilize the left SI joint or a combination of these factors.

It also appears doubtful that it is the increased tension in piriformis that is actually responsible for the external rotation of the right leg consistently noted with the 'alternate' presentations and right or left upslip. In the Schamberger study, of the 96 patients who presented with malalignment, all of the 37% who had increased tension in piriformis bilaterally showed an outwards rotation of one leg and an inwards rotation of the other, in a pattern in keeping with whether they were left anterior and locked (left outwards) or had one of the 'alternate' presentations (right outwards). In addition, the right piriformis showed an involvement in isolation three and six times as often as the left with the left anterior and locked and the 'alternate' presentations respectively.

Increased tone and recurrent spasm in one or other piriformis muscle is often blamed for a failure to correct the malalignment initially or for the recurrence of malalignment following correction. Its oblique attachment to the sacrum normally plays a vital role in stabilizing the SI joint on the side of single leg stance but has also been implicated as a cause of SI joint locking and sacral torsion.

The increased tension in piriformis can result in buttock and lower extremity pain on the basis of:

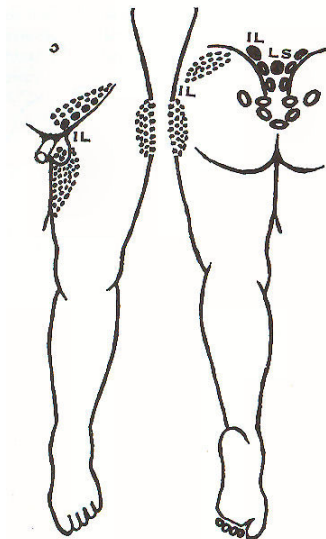
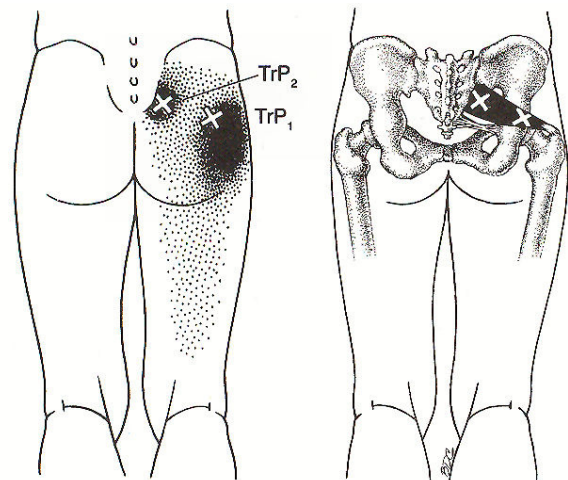
- ◆ referred pain, felt primarily in the posterior thigh region
- ◆ compromise and irritation of the sciatic nerve or its components.

Piriformis involvement can contribute to the deep pain associated with pelvic floor dysfunction, with increased tension and acute tenderness noted on palpation of piriformis per rectum or vagina.

### **The left hip abductors and TFL/ITB complex**

Gluteus medius, gluteus minimus and TFL, with its continuation as the ITB, show an involvement in practically all patients with malalignment regardless of the pattern of presentation. Pain in the region of the left hip, greater trochanter and lateral thigh and knee is certainly one of the more common presenting complaints. Increased tone and tenderness to palpation are usually evident on the left side. Tenderness is most likely to be found over the distal part of the left ITB, and less often, along the full length of the ITB, the TFL and the hip abductor origin and gluteus medius/minimus muscle mass.

*Composite pattern of pain (solid and stippled pattern) referred from trigger points (TrPs; marked by X) in the right piriformis muscle. The lateral X (TrP1) indicates the most common TrP location. The stippling locates the spillover pattern that may be felt as less intense pain than that of the essential pattern (solid black). Spillover may be absent.*



*Typical sites of referred pain from the left iliolumbar ligaments (IL), which are being irritated as a result of lumbosacral (LS) joint instability: the groin, the anterior medial upper two-thirds of the thigh, the lower abdomen above Poupart's ligament, the testicle in the male, the vagina in the female, the upper buttock beneath the crest of the ilium and the upper outer thigh.*

## **The thoracic paravertebral muscles**

Increased tone and tenderness to palpation most consistently involve the paravertebral muscles on either side of the lower half of the thoracic spine, in particular the erector spinalis and semispinalis thoracis, and less often iliocostalis and longissimus thoracis. Most often affected is the segment running from around the level of T3, T4 or T5 down to T12 or L1. Less frequently, the involvement is limited to one or both sides of the mid-thoracic (T3-T7) spine or the thoracolumbar junction area, sometimes immediately adjacent to a malrotated vertebra or vertebrae.

## **Quadratus lumborum**

Increased tension in quadratus lumborum has frequently been implicated in the recurrence of an upslip, rotational malalignment, vertebral rotation or combinations of these.

First, attachments to the twelfth rib and the posterior iliac crest allow this muscle to pull the innominate upwards.

Second, attachments to the posterior iliac crest and the iliolumbar ligament together exert an anterior rotational force on the innominate.

Third, attachments to the tips of the transverse processes of L1 to L4 inclusive exert a lateral and rotational force on these vertebrae and may play a role in determining the direction that a compensatory curve of the lumbar spine will assume. Alternatively, a malrotation of any of these vertebrae may facilitate the muscle on one side and inhibit its partner on the other. The frequently noted left rotation of the L1 vertebral complex (spinous process to the right) facilitates the left quadratus lumborum and inhibits that on the right.

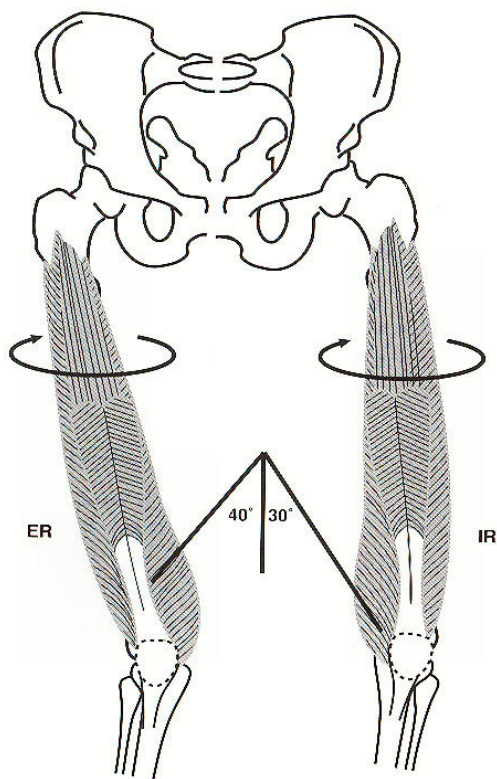
## The iliopsoas muscle

The three components that make up this conjoint muscle are all strategically placed. Psoas minor originates from the sides of the vertebral bodies of T12 to L5 and inserts into the superolateral aspect of the superior pubic ramus. Psoas major originates from the transverse processes of L1 to L5 and inserts into the lesser trochanter. Iliacus comes off the upper iliac fossa, iliac crest, anterior sacroiliac ligament and base of the sacrum; it inserts in part into the tendon of psoas major and in part directly into the lesser trochanter. Intermittent spasm of the iliopsoas probably accounts for the frequent report of a lancinating pain felt in the groin.

## Quadriceps

**Clinical correlation.** The reorientation of the components of the quadriceps muscle away from the sagittal plane on the side on which the lower extremity rotates externally with malalignment may:

- ◆ decrease their ability to contribute to advancing the leg in the sagittal plane
- ◆ result in a more rapid fatiguing of these muscles, which in turn would contribute to:
  - the muscles becoming sore as with overuse
  - that leg feeling weak and/ or unstable
  - an increasing tendency to valgus angulation at the knee, attributable in part to vastus medialis being weaker and fatiguing more rapidly



*The asymmetrical angulation of vastus medialis fibers with 'alternate' presentations and upslops: the right increased with external rotation and valgus angulation, the left decreased with internal rotation and varus angulation.*

- these changes, in combination with other factors cited, such as the tendency to pronation on that side and an increased tendency to lateral tracking of the patella, predisposing to the development of patellofemoral compartment syndrome

patellar tendonitis, which are typically much more common, or more severe, on the right side, given the preponderance of right lower extremity external rotation.

## ASYMMETRY OF LIGAMENT TENSION

Ligaments should feel neither lax nor excessively taut, and they should not be tender. A side-to-side comparison is invaluable for determining any differences. Malalignment can increase tension by:

- ◆ increasing the distance between the origin and insertion
- ◆ increasing tension in a muscle that attaches to, or is in continuity with, the ligament.

A persistent increase in tension in a ligament has four undesirable consequences.

- ◆ First, the ligament eventually lengthens and fails to provide adequate support.
- ◆ Second, the ligament ultimately becomes painful. The nerve fibers cannot elongate as much as the elastic components of a ligament and are therefore put under excessive stretch long before elongation of the elastic elements has reached its limit. Prechel & Powley have shown how lumbosacral ligaments and other connective tissues are innervated by small-calibre, primary afferent fibers that can send nociceptive stimuli to the spinal cord. When irritated, these same fibers can also secrete proinflammatory neuropeptides capable of initiating peptide release and a chain of events leading to eventual tissue inflammation and oedema. Connective tissue structures in this region are also supplied by sympathetic efferent axons capable of releasing catecholamines.

A balance between these two neural systems is thought to be important to the ‘maintenance of the integrity of the lumbosacral ligamentous structures’. The balance can presumably be upset with chronic excessive tension in the ligaments, which may help to explain why ligament inflammation and pain often fail to settle down until normal tension has been re-established by correction of the malalignment; the posterior pelvic ligaments are a prime example of this phenomenon.

In addition, the blood supply to the ligaments is already poor in comparison to that of other tissues and would be further compromised by any increase in tension and the associated catecholamine release with irritation of the sympathetic system.

- ◆ Third, an elongated, irritated and inflamed ligament can become a source of aberrant proprioceptive signals and referred pain symptoms. Trigger points can also develop in ligaments.
- ◆ Finally, pain from the ligaments results in a reflex splinting of muscles in the vicinity in an attempt to prevent further irritation of the ligaments. If the splinting is asymmetrical, it will predispose to the recurrence of malalignment. Chronic splinting eventually results in chronic tension myalgia and myofascial pain.

**Ligaments typically affected by malalignment:** iliolumbar ligament, sacrotuberous ligament, sacroiliac ligaments, sacrospinous ligament, ligaments spanning the pubic symphysis, the inguinal ligaments, the hip joint ligaments, the intervertebral ligaments, ligaments of the knee and ankle.

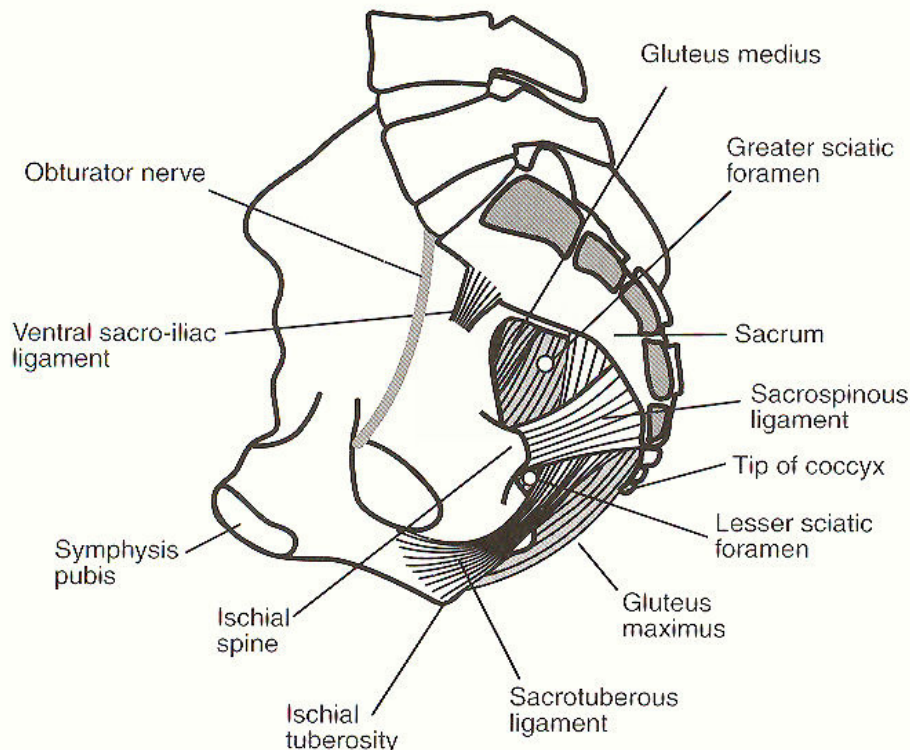
**Visceral symptoms caused by referral from ligaments:**

- ◆ Iliolumbar ligament
  - Ipsilateral testicular discomfort
  - Discomfort involving the penis
  - Unilateral vaginal or labial pain, with or without dyspareunia

- Unilateral groin pain, known to mimic appendicitis, because its location just above and medial to the inguinal ligaments is near McBurney's point
- Nausea
- ◆ Lumbosacral ligament
  - Bladder discomfort and a frequent urge to void, which can signal a recurrence of malalignment and may not be relieved by voiding; in addition to an involvement of this ligament, another mechanism to consider is a strictly mechanical one, malalignment having resulted in irritation of the bladder outlet by distorting the bladder and squeezing or twisting the bladder neck.
  - rectal pain, which can occur with laxity of the lower sacral ligaments.
- ◆ Sacroiliac ligaments
  - these may refer pain to the lower abdomen, possibly 'accompanied by tenderness' in that area.
- ◆ Lumbar and lumbosacral spine ligaments
  - irritation of these ligaments has been connected to bowel disturbance. Patients may experience an acute onset of diarrhea coincident with the recurrence of malalignment that is abolished by realignment. In others, recurrence is associated with episodes of severe constipation, bloating and 'gas'.

*Relation to activity and rest*

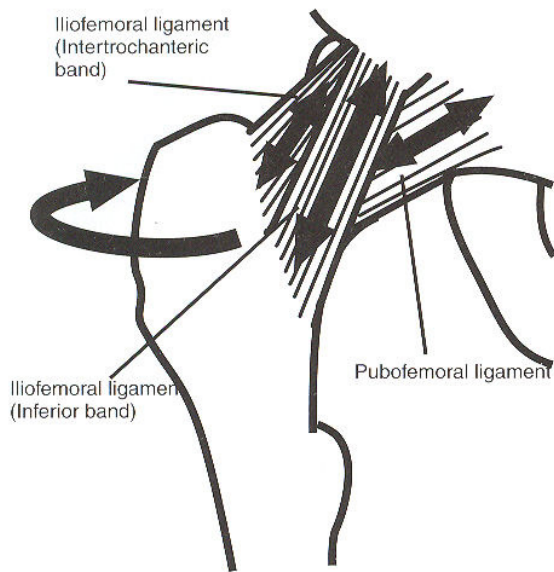
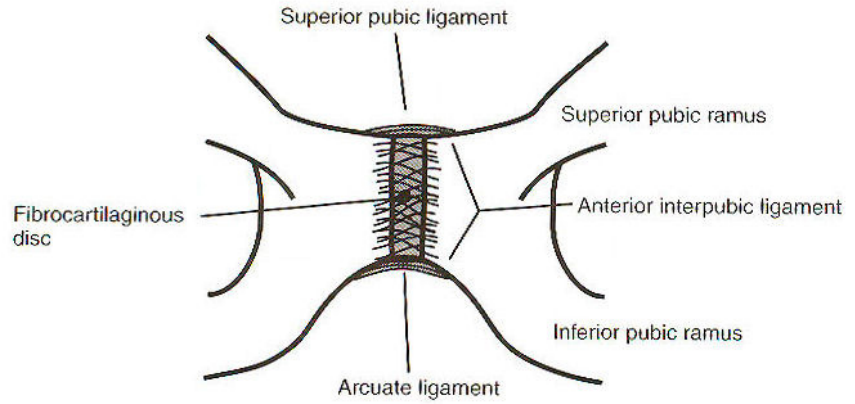
Referred pain from the irritation of ligaments, fascia and other connective tissue structures is a particular problem immediately on getting up from lying or sitting, tends to get better on moving about but may worsen again when the activity is continued for a longer period of time.



*Sacrospinous ligament on a lateral view from the inside of the pelvis*

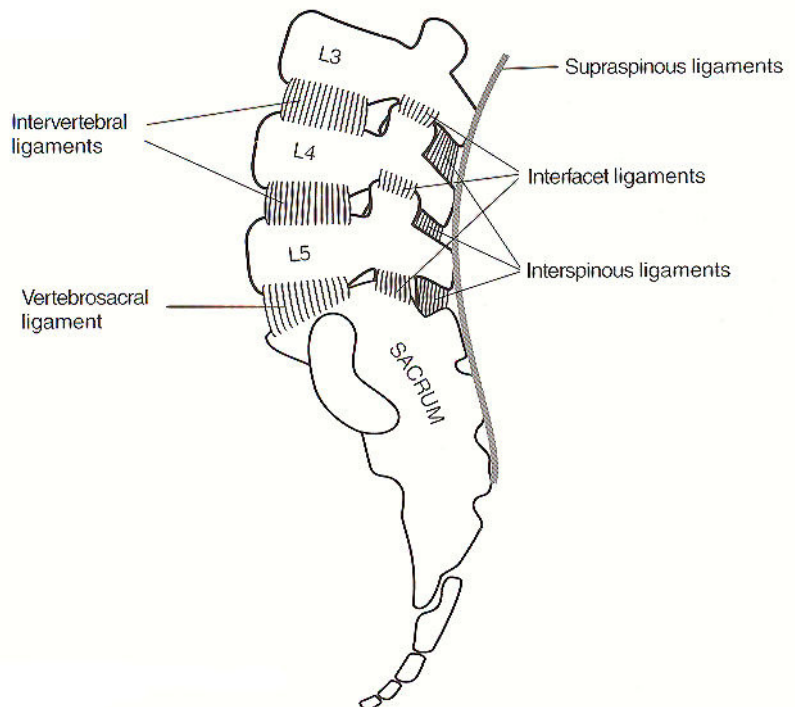


*Ligaments around the symphysis pubis*



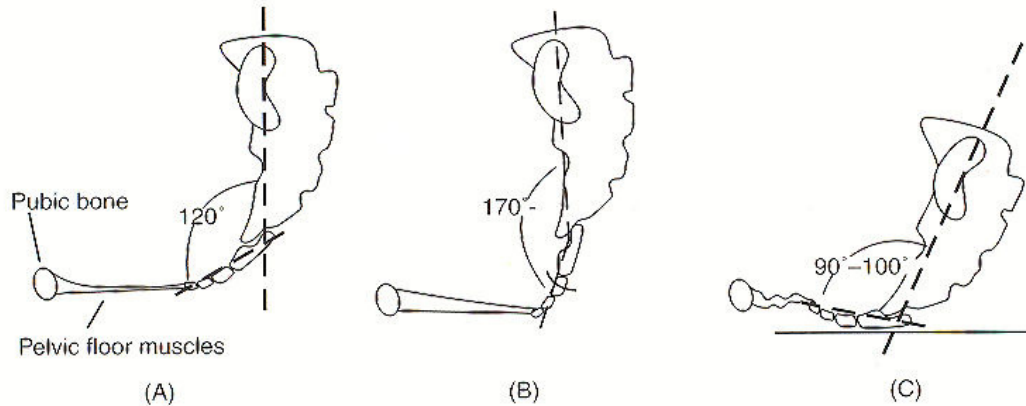
*Anterior hip joint capsule and iliofemoral and pubofemoral ligaments subjected to a torsional stress with malalignment-related external rotation of the right lower extremity.*

*Ligaments connecting the vertebrae to each other and to the sacrum*



## Coccydynia, pelvic floor dystonia and levator ani syndrome

Involvement of the coccygeal region is not uncommon in association with malalignment. Schamberger found that 12% of those presenting with malalignment had tenderness over the coccyx.



*Effect of angulation of the coccyx on the inserting ligaments and pelvic floor muscles.*

*(A) A normal angulation of 120 degrees relative to the sacrum, with a 30 degree range of motion; there is normal pelvic floor tone.*

*(B) Excessive extension angulation resulting in hypertonus of the pelvic floor.*

*(C) Excessive flexion angulation resulting in hypotonus of the pelvic floor (e.g. on 'slouched sitting') but which may itself result from a chronic hypertonus.*

Heardman pointed out that there are fascial connections between the levator ani muscles and the piriformis, biceps femoris, semitendinosus and obturator internus muscles, so that tension in any of these muscles can affect the tone of the pelvic floor. The smooth muscle diaphragm and endopelvic diaphragm complete the floor.

The pudendal nerve and vessels that supply these muscles travel within the fascial layers, which puts them at risk of being irritated or compressed by any abnormal increase in tension and/ or contracture of these myofascial tissues. Any compromise of the neurovascular supply can result in spasm, trophic changes, vasomotor effects and pain involving the pelvic floor structures.

Pelvic malalignment distorts the ring formed by the pelvic bones and therefore disturbs the points of attachment of the pelvic floor muscles. This affects the tone in these muscles. It also puts a twist on structures that exit by traversing the pelvic floor (the urethra and distal rectum/anus) or lie in close proximity to the pelvic floor (the vagina, uterus, bladder and rectum).

### *Levator ani syndrome*

Levator ani syndrome, also called levator spasm syndrome, may result from a persistent increase in pelvic floor tension. Acute trauma to the sacrococcygeal region, such as from a fall, direct blow or unaccustomed and prolonged pressure from a poor sitting posture, can result in reflex hypertonicity of

the levator muscles. As Selby has pointed out, this may create further irritating deformation of the joint in the same anterior direction as the original traumatic insult...This scenario can go on for years, fuelled by sitting in soft chairs and certain car seats (e.g. bucket seats). However, simple manoeuvres (e.g. direct mobilization of the sacrococcygeal joint) that break into the vicious cycle can often totally alleviate this sort of distress, both acute and chronic, in short order.

A history of trauma to the coccyx is often overlooked or hard to come by in patients who have sustained an injury many years ago. Specific questions may trigger a memory of a tobogganing accident or of a fall from a bike or down a staircase. Patients are less likely to recall specific incidents if their activity is one in which falls are par for the course. Sexual abuse is another cause to consider.

In female patients, questions repeatedly bring forth the realization that the symptoms that have now brought them to the doctor's office have, in retrospect, been present since the time of a pregnancy and delivery. Birth trauma and inadequate postpartum strengthening are very likely to result in excessive relaxation of the pelvic floor. This subject is now being studied extensively.

In Shelby's experience, spinal pain due to coccyx strain and hypertonicity of the pelvic floor is commonly felt in the mid to low sacral area referring outward toward the greater trochanter unilaterally or bilaterally (resembling trochanteric bursitis) and not infrequently down the posterior thigh.

He has also documented cases of chronic groin and anterior thigh pain that completely resolved following mobilization of the coccyx. Symptoms are typically provoked by sitting in soft chairs and by prolonged standing and repetitive activities such as stair-climbing that 'demand effort from the pelvic floor muscles to contract in order to stabilize the pelvis and thus are potentially provocative'.

In this respect, Baker points out that gluteus maximus has tendinous attachments to the sacrococcygeal capsule, and that reproduction of the pelvic floor pain with resisted hip extension (e.g. stair-climbing) 'is indicative of coccyx dysfunction due to that relationship'.

## **CONCLUSION**

Medical fashions, unlike designer fashions, tend to die hard. It should therefore come as no surprise that the misconceptions surrounding the SI joint persisted for five decades. These misconceptions were initially instilled into a whole generation of doctors, who in turn used their authority and vested interests to promote the errors and foist them onto the next generation, no questions asked. So it has come to be that the SI joint has the honor of being the only joint in the body that for some reason cannot move the therefore cannot cause pain.

The days of looking at an injury in isolation are over.

A recognition of the malalignment syndrome will hopefully lead to a greater awareness of these various kinetic chains, their interactions and the appropriate treatment process, not least of which is the involvement of the patient on a day-by-day basis to ensure its success.

## **References**

Schamberger, W 2002: The Malalignment Syndrome: Implications for Medicine and Sport. Churchill Livingstone, Edinburgh, 2, 96-97, 99-102, 104, 106, 108, 110, 128-130, 132, 134-135, 137-139, 141, 143, 155-156, 161-163, 209, 237-240, 402-403.