

# Critical Analysis of the Functional Dynamics of the Sacroiliac Joints as They Pertain to Normal Gait

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## Abstract

The purpose of this paper is to describe the basic structure of the sacroiliac joint, the loading sequence of the primary ligaments, its function during normal gait and the supportive muscle functions. The goal of treatment of low back and pelvic pain should be the restoration of normal function and so it is important to understand just how the low back and the pelvis normally function.

The sacroiliac joint has been assumed to be structurally so strong as to be immune to injury through minor trauma. Motion in the joint is minimal and its function has been obscure. There is essentially no motion in the sacroiliac joint on a transverse axis when the sacrum is loaded with the superincumbent weight and the pelvis is symmetrical as in relaxed standing. During normal gait, however, when the pelvis moves into asymmetry, the sacrum flexes laterally and rotates toward the side of loading to drive rotation and counter rotation of the trunk during normal gait to decrease the loading impulse. Primary loading of the superincumbent weight on the sacrum is on the posterior interosseous ligaments with a secondary loading on the sacrotuberous and sacrospinous ligaments. It is the secondary loading that draws these joints together in a critical balance of loading forces. The result of this loading is to create a force couple. The sacroiliac joints function as self-compensating, interdependent force couples with force-dependent transverse and oblique axes of rotation to absorb, modify and redirect forces such as linear and angular momentum, linear and angular acceleration and deceleration, loading and unloading and others.

**Key Words:** *Biomechanics, normal gait, sacroiliac joint*

## Introduction

The pelvis has a certain Zen quality, a source of both exquisite pleasure and exquisite pain. The sacroiliac joints appear nearly immobile with such slight movement that there also appears to be only minimal function in these joints and structurally so strong as they appear to be immune to injury from minor trauma. Nothing is to be gained by not investigating these assumptions and certainly nothing is to be gained by continuing to treat low back pain in the same way that it has always been treated. A critical analysis is essential to understanding the movement and the functional biomechanics of the sacroiliac joints because it is only through understanding normal function that it is

possible to understand how pathology varies from normal function. Treatment for pathology must be the restoration of normal function.

## Anatomy

The sacroiliac joint is composed of an early fusion of the S1, S2 and S3 sacral segments. It has an unusual and underdeveloped iliac cartilage surface with a layer of hyaline cartilage on the sacral surface two to three times thicker than the fibrocartilage on the ilial surface. A crescent shaped ridge develops along the length of the iliac surface with a congruent concavity on the sacral side. The surfaces become more

irregular and prominent with aging and the effect is to gain stability at the expense of mobility. (Cassidy, 1992) This is a high friction joint. (Vleeming, 1990)

An understanding of the structural angulations of the sacroiliac joints is essential to any analysis of the functional biomechanics. The structural angle of each S1 segment is about 20 degrees off sagittal anterolateral and that of each S3 segment off sagittal about 5 degrees posterolateral. The sum of the angles for both S1 segments is about 40 degrees and for both S3 segments is about 10 degrees. (Fig. 1) (Dijkstra, 1989)

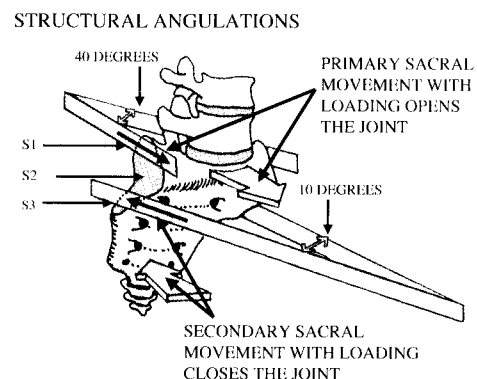


FIG. 1

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*Fig 1. The structural angulations of the sacroiliac joints appear to allow the sacrum to move ventrally at the S1 segment with primary loading of the posterior ligaments and dorsally at the S3 segment with the secondary loading of the sacrotuberous and sacrospinous ligaments. The S1 sacral segment moves anteriorly on the corresponding S1 ilial segment and the S3 sacral segment moves posteriorly on the corresponding S3 ilial segment as the ilial convexity moves into the sacral concavity.*

## Loading Sequence

When moving from supine to relaxed standing the sacrum is loaded with the superincumbent weight. Primary vertebral loading on the sacral promontory causes the sacrum to incline ventrally increasing the tensile stress on the posterior interosseous ligaments. This causes a tendency for the caudal end of the sacrum to move posteriorly causing a counter-balancing tensile stress on the sacrotuberous and sacrospinous ligaments. (DonTigny, 1994) Here it is extremely important to note that the primary movement with loading at S1 is a ventral force, however the secondary movement at S3 is dorsal. The secondary movement must overcome the primary movement and pull both of the S1 sacral segments more or less snugly into both of the S1 ilial segments to stabilize the sacroiliac joints and the pelvis. (Fig. 2)

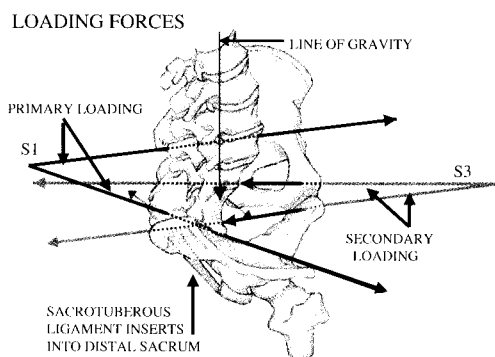


Fig 2. The secondary loading at S3 must balance the primary loading at S1. For this to occur some leverage is necessary. This leverage is provided by the distal attachment on the sacrum of the sacrotuberous ligament. A critical balance of forces is achieved.

It is also important to notice that to overcome the ventral force and to pull S1 posteriorly, leverage is required. The sacrotuberous ligaments through their attachment to the distal sacrum apply this leverage. The direction of the pull on these ligaments is lateral and oblique from their other attachment to the ischial tuberosities, which minimizes friction and compression both at S3 and at S1. (Fig.3)

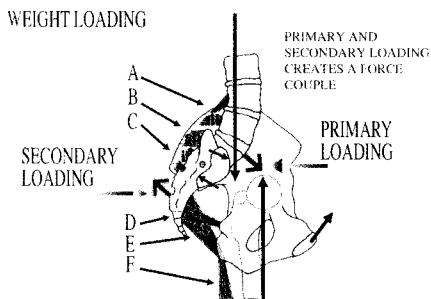


Fig 3. Primary weight loading is on the iliolumbar ligaments (A), the short posterior sacroiliac ligaments (B), and the posterior interosseous ligaments (C). Secondary loading is on the sacrospinous (D) and sacrotuberous ligaments (E). The hamstrings (F) reinforce the secondary loading. The primary loading tends to separate the joints and the secondary loading brings the joints tightly together. The result of this loading is a force couple. A force dependent transverse axis is midway between the coupled forces.

Vleeming found that increasing tension on the sacrotuberous ligament increases friction in the sacroiliac joint (Vleeming, 1989).

When the posterior interosseous and the sacrotuberous ligaments are loaded the opposing forces create a force couple (Fig. 4). (DonTigny, 1994)

### FORCE COUPLE

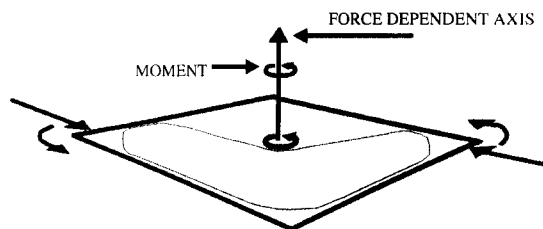


Fig. 4. A couple is two equal and parallel forces acting in opposite directions and resulting in a pure moment. A moment is a vector quantity and is described as the tendency to rotate about an axis. Thus a force dependent axis is formed perpendicular to the structure.

### AXES OF ROTATION

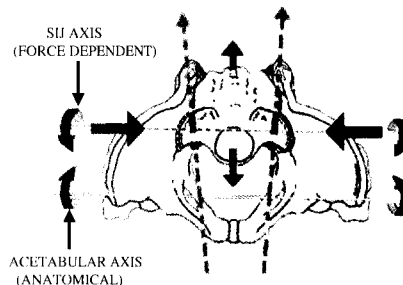


Fig. 5. In the pelvis there are two transverse axes of rotation, the force dependent transverse axis of the sacroiliac joints and the anatomical transverse axis of the hip joints. The line of gravity causes an anterior rotation of the sacrum at the sacroiliac joints and a posterior rotation of the pelvis at the hip joints, tightening the sacrotuberous ligament and stabilizing the sacroiliac joints.

The moment created by the force couple creates a force-dependent transverse axis of rotation for the sacroiliac joints. (Fig.5) The transverse axis of the sacroiliac joint is not anatomically dependent, but rather force dependent. (DonTigny, 1994)

The primary loading force at S1 is more or less constant, dependent on the superincumbent weight and will increase with load carrying. The secondary loading at S3 is dependent upon the line of gravity remaining behind the acetabular axis and a resultant posterior innominate rotation, which maintains tension on the sacrotuberous and sacrospinous ligaments to balance the force at S1. Stability is adequate when the pelvis is symmetrical and tension remains on the sacrotuberous ligaments, however this is a critical balance of forces and the joint is vulnerable to any shift in the line of gravity anterior to the acetabula, which

will loosen the sacrotuberous ligaments and may result in a subluxation in anterior rotation. (DonTigny, 1994)

Vukicevic (1991) found that in the normal standing posture the sacroiliac joints can withstand a wide range of loading without pelvic or sacral deformation, even after the elimination of the sacrotuberous and sacrospinous ligaments. The joint surfaces do not approximate with this loading, however, these joints become profoundly unstable after the removal of the posterior interosseous ligaments. The sacroiliac joint is essentially a non-weight-bearing joint. (Cunningham, 1906)

Although the primary loading of the posterior interosseous ligaments has the potential of causing a visco-elastic failure of the collagen, the immediate secondary loading of the sacrotuberous ligaments draws the joints together pulls the ilial convexity into the sacral concavity, probably increasing friction somewhat, preventing further motion and thus limits further ligamentous loading. The congruency of the opposing joint surfaces (Vleeming, 1990) allows increased ligamentous loading without the increased risk of collagen failure. Vleeming referred to this locking as self-bracing. (Vleeming, 1990)

When the line of gravity is posterior to the acetabula, the innominate bones rotate posteriorly on an acetabular axis, tightening the sacrotuberous ligaments, and increasing self-bracing and stability. (DonTigny, 1994) Once the sacroiliac joints are self-braced, loading may be increased without causing further movement at the sacroiliac joint. (Vleeming, 1990)

The movement of the sacrum that occurs when moving from supine to relaxed standing during loading and self-bracing is not the same as the movement that occurs after the sacrum is loaded. Movement of the loaded sacrum occurs as a consequence of innominate movement and not independently

## The Lateral Sacral Flexion and Rotation

When the sacrum is loaded only slight movement occurs on a transverse sacroiliac axis on the symmetrical pelvis (Sturresson), however, on the asymmetric pelvis movement of the sacrum occurs as a result of innominate movement. When moving from relaxed standing to the asymmetric pelvis during normal ambulation with initial contact on the right, the right innominate rotates slightly posteriorly causing the posterior interosseous ligaments to pull the sacrum down on the right. The left innominate rotates slightly anteriorly causing the posterior interosseous ligaments to lift the sacrum on the left causing it to be inclined laterally toward the side of loading. This innominate rotation occurs on axes through the pubic symphysis. (Lavignolle, 1984) The resultant lateral sacral flexion causes the sacroiliac joints to close at S1 on the right and at S3 on the left in order to establish a force-dependent oblique axis of rotation. (Fig. 6,7) The superincumbent weight being anterior to the body of the



Fig. 6. During normal gait, as the innominate on the side of loading (right) rotates posteriorly the sacrum is "gripped" by the posterior interosseous ligaments and moves caudad closing the sacroiliac joint at S1 and opening it at S3. The innominate on the side of the trailing leg (left) rotates anteriorly and the sacrum on that side is also "gripped" by the posterior interosseous ligaments and moves cephalad closing the sacroiliac joint at S3 and opening it at S1. The sacrum is caused to flex laterally creating a force dependent oblique axis from S1 right to S3 left.

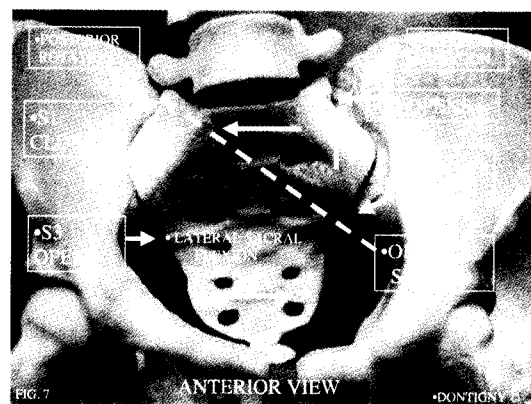


Fig. 7. Anterior view of the pelvis, loading is on the right. The oblique axis is from S1 right to S3 left and the sacrum is flexed laterally toward the right side.

sacrum causes the sacrum to rotate on that oblique axis, anteriorly at S1 on the left and posteriorly at S3 on the right (Fig. 8) to drive rotation of the trunk in the direction of the loading force. This rotation precedes loading to minimize and absorb the loading force to preserve the systems and to minimize lumbar torsion and thus shear and torsion shear to the disks.

The sacroiliac joints function as interdependent, self-compensating force couples with force-dependent transverse and oblique axes of rotation. These force couples modify, absorb and transfer forces such as linear and angular acceleration and deceleration, linear and angular momentum, impact loading and unloading and others. Force couples enhance function by storing and releasing energy, preserve the systems and prevent injury by decreasing loading forces. (DonTigny, 1994)

SACRAL MOVEMENT ON OBLIQUE SIJ AXIS

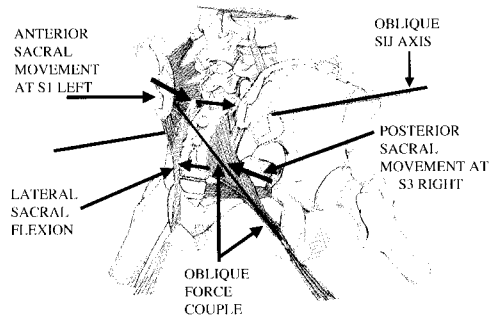


Fig. 8. At initial contact, the pelvis is asymmetrical. The right innominate is posteriorly rotated and the left innominate is anteriorly rotated. The sacrum is flexed laterally to the right and the joint surfaces at sacral S1 and ilial S1 on the right and the joint surfaces at sacral S3 and ilial S3 on the left approximate. This establishes a force-dependent oblique axis of rotation for the sacroiliac joint.

The joint surfaces at sacral S1 and ilial S1 on the left and at sacral S3 and ilial S3 on the right separate. Because the line of gravity is anterior to the sacroiliac joints, oblique movement occurs on the oblique axis toward the side of loading, anteriorly at S1 right and posteriorly at S3 left. This movement is allowed by the unique structural angulations of the sacroiliac joints and drives rotation and counter rotation of the trunk

### Demonstration of The Lateral Sacral Flexion and Rotation

While sitting with the feet flat on the floor put your index finger on the tip of your coccyx. Now translate or project your right thigh forward and your left back and feel your sacrum cant laterally back and forth to create an oblique axis of rotation as you translate your legs (Fig. 9).

DEMONSTRATION OF LATERAL SACRAL FLEXION

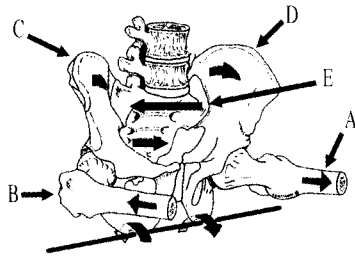


Fig. 9. When seated, project the left leg (A) and retract the right leg (B) creating an asymmetric pelvis. The right innominate rotates posteriorly (C), the left innominate rotates anteriorly (D) and the sacrum will flex laterally to the right (E) creating a force dependent oblique axis of rotation. Put one finger on your coccyx and feel it move back and forth as you translate your legs forward and back. Now hold the right thigh back and the left forward and bend your trunk down and rotate it to the left to feel the sacrum incline ventrally on the oblique axis.

Now hold the right thigh back and the left forward as you bend your trunk down and rotate it to the right to feel your sacrum incline ventrally while moving on that oblique axis.

Now while holding the right thigh retracted and the left projected, turn your trunk to the right and then to the left.

Note how rotation to the right is facilitated and how rotation to the left is inhibited. Now, hold both thighs neutral and turn to the right and then to the left. Note how you facilitate the turning by retracting and projecting your thighs to create pelvic asymmetry.

### Function During Normal Gait

With initial contact on the right foot when ambulating, the right innominate is rotated somewhat posteriorly and the left innominate (on the side of the trailing leg) is rotated somewhat anteriorly. The sacrum is canted to the right. The sacroiliac joint on the right is approximated at the S1 segment and on the left at the S3 segment establishing a force dependent oblique axis. The unique structural angulations of the sacroiliac joints allow the joints to open at S1 on the left and S3 on the right and the sacrum moves anteriorly at S1 left and posteriorly at S3 right, driving trunk rotation to the right. (Fig. 8) (Also see Normal Gait sequence)

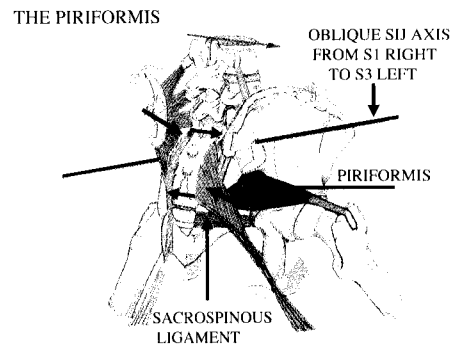


Fig. 10. Note how the piriformis supports the function of the sacrospinous ligament to act on lateral sacral flexion to restore the sacrum to neutral as the pelvis moves to symmetry at midstep when the bearing leg is perpendicular.

Note in Fig. 10 how the piriformis muscle supports the function of the sacrospinous ligament as it works to straighten the lateral sacral cant. Similarly in Fig. 11 note

THE GLUTEUS MAXIMUS

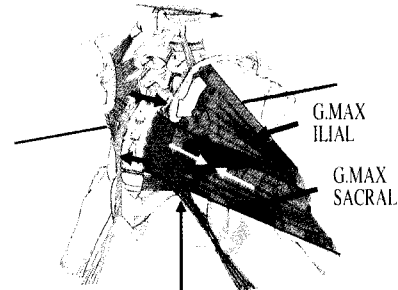


Fig. 11. Note how the sacral origin of the gluteus maximus works with the piriformis to support the function of the sacrotuberous ligament and to straighten the sacrum as it pulls the body forward until the leg is perpendicular and the pelvis is symmetrical.

how the sacral origin of the gluteus maximus both pulls the body forward until the leg is perpendicular and the pelvis is symmetrical, and works with the piriformis to support the

sacrospinous ligament by also functioning to straighten the lateral sacral cant. (See *Normal Gait sequence, 3 and 10*) The *piriformis* and the sacral origin of the *gluteus maximus* can probably be considered as prime movers of the sacroiliac joint when the pelvis is asymmetrical.

It is also worthwhile noting at this time how, with a lesion of the sacroiliac joints whereby the innominate bones may subluxate (partially dislocate) and move cephalad and laterally on the sacrum, the sacral origin of the *gluteus maximus* may be separated from its ilial origin and the origin of the *piriformis* muscle on the anterior surface of the sacrum may be separated and strained from its secondary origin at the superior margin of the greater sciatic notch. (DonTigny, 1990, 1994, 2000) With each step the sacrum is uniquely positioned by the innominate bones to drive rotation and counter rotation of the upper trunk with minimal torsion to the lumbar spine. This provides for the storage and release of energy in the adjacent ligaments through the interaction of the force couples. The alternate canting causes an oscillation of the sacrum during normal gait. Pierrinowski (1988) described this sacral oscillation as being in a figure eight pattern. (See *Normal Gait sequence 3, 8, 10 and 11*)

## Function of The Lateral Sacral Cant

Pelvic asymmetry and the lateral sacral cant are increased with the length of the stride as is the force of impact. The lateral sacral cant inclines the sacral base toward the side of initial contact and drives rotation of the spine posteriorly in the direction of the deceleration force of loading to ease the force of impact. The greater the lateral sacral flexion, the greater the counter rotation, which serves to lessen the increased impact impulse.

## Rhythmic Sacrocranial Vertebral Oscillation (RSVO)

With ambulation, at mid stance, prior to initial contact, the trunk is falling anteriorly with inertial and gravitational force vectors off of the weight bearing leg that is now perpendicular to the ground. (DonTigny, 1990) Lateral sacral flexion and rotation increase the lumbar, lordosis and the deceleration of initial contact halts the horizontal pelvic swing. The anterior inclination of the trunk is reversed as pelvic asymmetry reverses after loading at two-point support, causing a sequential rhythmic increase and then flattening of the spinal curves from the sacrum, cephalad. A posterior recovery motion occurs with the reversal of asymmetry. (Thorstensson et al, 1984) which facilitates the hip flexors of the trailing leg in the initiation of the next step. (DonTigny, 1990) (See accelerometer studies from Liberson et al in the *Normal Gait sequence, 3,4,5*)

Thus, as the sacrum oscillates with repetitive asymmetry so do the spinal curves. In treadmill studies Thorstensson (1984) found the excursion of this rhythmic sacrocranial vertebral oscillation (RSVO) to be about 2-2.5 cm at L3 and

about 1-1.5 cm at C7. This movement reflects the movement of the sacrum on the oblique, force dependent axis on the asymmetric pelvis with a return to neutral when the pelvis is symmetrical on the perpendicular leg.

## RSVO Function

At initial contact when the pelvis is asymmetrical and the sacrum is inclined toward the side of loading, the spinal curves are increased with the increase in lordosis and the spine is rotated toward the loaded side. The trunk rotates in the same direction as the impact impulse (deceleration force), precedes the impact impulse and serves to lessen the loading force to preserve the systems. ( Fig. 12)

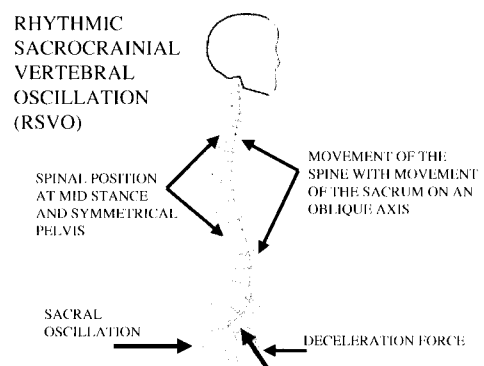


Fig. 12. When sacral motion occurs on the oblique axis, it causes an increase in lordosis in the spinal curves with asymmetry and then a flattening of the spinal curves at mid-stance when the pelvis is again symmetrical. The spine oscillates once each step and twice each stride from the sacrum cephalad. The decreasing waveform of the spine damps this oscillation to keep the head steady. The sacrum oscillates in a figure 8 pattern.

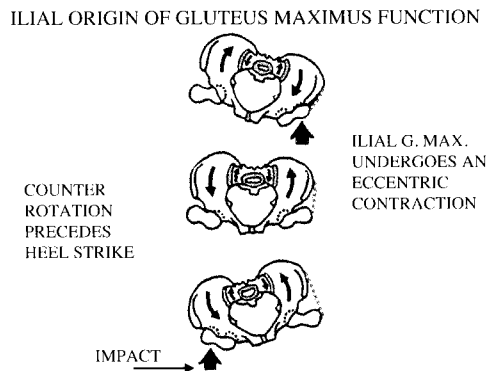
With rotation and counter rotation of the spine during normal ambulation it follows that rotation of the vertebra must torque the annulus, decreasing the height of the disks. The disks are mostly water and water is not compressible so part of the loading force is briefly stored in the annulus. The torsion force is released, the spinal curves straighten at mid-stance when the pelvis is again symmetrical and then rotate in the other direction with the next step, storing and releasing energy.

During this rhythmic sacrocranial vertebral oscillation the spine functions as a decreasing waveform to damp this oscillation and to keep the head stable. This is a highly functional biological image stabilizing system and assists the observer in such activities as observing pelvic dynamics in random subjects in vivo. (Fig. 12) (See *Normal Gait sequence 4,10,11*)

## Eccentric Contraction of The Gluteus Maximus

Following heel strike, the sacral origin of the ipsilateral *gluteus maximus* works with the *piriformis* to support the sacrotuberous ligament, to restore the sacrum to its neutral position and then to pull the body forward until the leg is

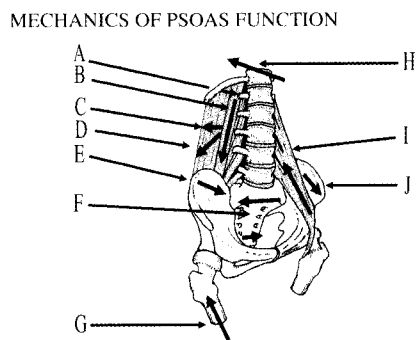
perpendicular to the ground at the single support phase and then the ilial origin of the gluteus maximus undergoes an eccentric contraction to decelerate and decrease impact loading on the contra lateral side. *Fig. 13 (DonTigny, 1990) (See Normal Gait sequence 3 and 10)*



*Fig 13. The ilial origin of the gluteus maximus undergoes an eccentric contraction as it decelerates the contra lateral side to decrease loading at initial contact. Contra rotation precedes impact and also serves to decrease the loading force. (Courtesy of Physical Therapy (DonTigny, 1990)*

## Muscle Functions in Support of The Contra Lateral Psoas

Following initial heel strike on the right, during normal ambulation, the right multifidus probably helps to extend the spine and facilitate rotation toward the left side, and supports the function of the left psoas as it brings the trailing leg forward. The right quadratus lumborum, the right abdominal obliques and the right transversus abdominis all appear to assist in this function. *Fig. 14 (See Normal Gait sequence 3,4,5)*



*Fig. 14. The posterior recovery from sacral movement on the oblique axis (H) facilitates the function of the psoas (I), and as the pelvis is moved toward symmetry, the anterior innominate rotation (J) is reversed also facilitating the psoas. As the trailing leg is brought forward, the spine is straightened and stabilized on the side of loading by the multifidus (A), the quadratus lumborum (B), the transversus abdominis (C), and the abdominal obliques (D). The right innominate rotates anteriorly (E) to symmetry at mid-stance and the laterally inclined sacrum (F) straightens to symmetry and then cants in the other direction. Impact loading is on the right (G).*

## The Hamstrings

The hamstrings have several interesting functions:

1. When standing and leaning forward to perform some task the hamstrings support the innominate bones and through the sacrotuberous ligament, the sacrum.
2. To work with the quadriceps and pull the knee posteriorly into terminal extension during normal gait after initial contact. *(DonTigny, 1972) (See Normal Gait sequence 1)*
3. To stabilize the knee in extension while working with the quadriceps and the gastrocnemius during normal gait. *(See Normal Gait sequence 1)*
4. Because the hamstrings insert laterally and distal to the knee they will provide lateral stability to the knee in extension. *(See Normal Gait sequence 5)*
5. To pull the body forward over the side of initial contact until the leg is perpendicular at mid-stance and then: *(See Normal Gait sequence 3)*
6. To work with the ilial origin of the gluteus maximus and the gastrocnemius to decelerate and ease impact loading on the contra lateral side as the body falls forward off of the perpendicular leg. *(See Normal Gait sequence 7)*

## The Peroneus Longus

The peroneus longus stabilizes the cuneiform and the first metatarsal during normal gait and provides up to 18% of the stability of the sacrotuberous ligament through the kinetic chain during mid and terminal stance. *(Wingerden, 1994) (See Normal Gait sequence 1,2,13)*

## Gastrocnemius and Toe Flexors

At the terminal double support phase of normal gait, the gastrocnemius and toe flexors of the trailing leg, decelerate the contra lateral side of initial contact to ease the force of loading. This is not a 'push-off'. Deceleration continues off the toe of the foot until loading occurs on the contra lateral side. *(See Normal Gait sequence 2,3,4,9,15)*

## The Abdominal Muscles

The rectus abdominis supports the anterior pelvis to stabilize the lumbar spine and sacroiliac joints when leaning forward to perform a task. The abdominal obliques also support the anterior pelvis and control pelvic rotation during normal ambulation. The transversus abdominis probably provides support for the ipsilateral multifidus, the ipsilateral quadratus lumborum and the contra lateral psoas during normal ambulation. *(See Normal Gait sequence 4, 10)*

## The Psoas Major

The psoas major is an important stabilizer of the lumbar spine when the subject is erect and the pelvis is symmetrical. Free body diagrams indicate that the psoas

contributes to forces across the sacroiliac joint. These forces include: posterior rotation of the pelvis, and force closure to the sacroiliac joint and the pubic symphysis. The dominant force of the bilateral psoas is axial compression. The psoas major also links the diaphragm with the pelvic floor. (*Gibbons, 2001*)

### Discussion

The stability of the sacroiliac joints when the joint is loaded and the pelvis is symmetrical depends upon a critical balance between the primary and secondary loading forces. During normal gait, the innominate bone on the side of initial contact rotates somewhat posteriorly, while the one on the side of the trailing leg moves somewhat anteriorly. The sacrum is canted (inclined) toward the side of loading and creates a force-dependent oblique axis of rotation.

The sacroiliac joints then move on that force dependent oblique axis to drive rotation and counter rotation during normal gait. The sacroiliac joints are dynamic joints and function as self-compensating, interdependent force couples with force-dependent transverse and oblique axes of rotation. They function to absorb, redirect and modify forces of linear and angular acceleration and deceleration, linear and angular momentum, loading and unloading and others in order to enhance gait and preserve the systems.

The key to dysfunction of the sacroiliac joints is in the loading sequence. It is the secondary loading of the sacrotuberous ligaments that draws the joints together and posterior rotation of the innominates on the sacrum enhances this effect to further increase self-bracing. Most dysfunction of the sacroiliac joints occurs when leaning forward to perform some task. When you lean forward to perform some task, the line of gravity moves anterior to the acetabula and the innominate bones will rotate anteriorly on an acetabular axis loosening the sacrotuberous ligament. Friction is decreased, the force couple is lost, the force-dependent axis of rotation is lost and the innominates will sublaxate cephalad and laterally on the sacrum at the S3 segment on an acetabular axis. (*DonTigny, 1994*)

This is a commonly overlooked condition and is easily corrected by manually moving the innominate posteriorly on the sacrum to the self-bracing position. (*DonTigny, 1990, 1994, 2000*) Correction will provide immediate relief of pain to most people with low back pain.

The effects of dysfunction on normal gait will be discussed in the next article.

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# Sequence of Normal Gait

## Normal Gait Illustrations 1-15

Accelerometer studies from data of Ducroquet, Joseph and Liberson, compiled by Liberson, WT, Loyola and Veterans Administration Hospital, Hines, IL. North American Academy of Manipulative Medicine meeting, San Francisco, 1966, handout with additions on muscle and joint function by DonTigny.

**•NORMAL GAIT** •FIG. 1

**•INITIAL DOUBLE SUPPORT**

**•ASYMMETRIC PELVIS**

**•SACRUM FLEXES LATERALLY**

**•HAMSTRINGS AND GASTROCNEMIUS STABILIZE THE KNEE AND DECELERATE THE CONTRA LATERAL SIDE**

**•PERONEUS LONGUS STABILIZES THE CUNEIFORM AND FIRST METATARSAL**

**•ACCELEROMETER VECTORS**

**•TRUNK IS COUNTER ROTATED AND MOVING ANTERIORLY**

**•QUADRICEPS AND HAMSTRINGS EXTEND AND STABILIZE THE KNEE**

**•ANTERIOR TIBIALIS DECELERATES THE FOOT**

•DONTIGNY ©

**•NORMAL GAIT** •FIG. 2

**•WEIGHT LOADING LEFT**

**•TRUNK IS DECELERATING**

**•DECELERATION FORCE OF LOADING SLOWS THE ANTERIOR MOTION OF THE UPPER BODY**

**•GASTROCNEMIUS IS DECELERATING THE CONTRA LATERAL SIDE**

**•PERONEUS IS STABILIZING THE CUNEIFORM AND METATARSAL**

**•THE QUADRICEPS AND HAMSTRINGS ALLOW SOME KNEE FLEXION TO CUSHION IMPACT LOADING**

•DONTIGNY ©

**•NORMAL GAIT** •FIG. 3

**•TRUNK REVERSAL**

**•THE POSTERIOR MOVEMENT OF THE UPPER BODY WITH REVERSAL OF ASYMMETRY FACILITATES THE HIP FLEXORS IN THE FORWARD PROPULSION OF THE TRAILING LEG**

**•THE SACRAL ORIGIN OF THE LEFT GLUTEUS MAXIMUS WORKS WITH THE LEFT PIRIFORMIS TO PULL THE SACRUM TO NEUTRAL AND TO PULL THE BODY FORWARD**

**•THE IPSILATERAL INNOMINATE ON THE SIDE OF WEIGHT LOADING DECELERATES ALTHOUGH THE CONTRA LATERAL INNOMINATE CONTINUES ANTERIORLY IN THE HORIZONTAL PLANE.**

**•HAMSTRINGS ALSO PULL THE BODY FORWARD UNTIL THE LEG IS PERPENDICULAR AND SEEM TO BE AIDED BY THE HIP ADDUCTORS**

•DONTIGNY ©

**•NORMAL GAIT (TERMINAL DOUBLE SUPPORT)** •FIG. 4

**•RHYTHMIC SACROCRANIAL VERTEBRAL OSCILLATION**

**•OBLIQUE AXIS OF SJJ**

**•THE EXCURSION OF THIS OSCILLATION IS ABOUT 2.5 CM AT L3 AND 1-1.5 CM AT C7 (THORSTENSSON)**

**•THE SPINAL CURVES DAMP THIS OSCILLATION TO MINIMIZE HEAD MOVEMENT**

**•DECELERATION CONTINUES UNTIL TOE OFF TO MINIMIZE THE CONTRA LATERAL LOADING IMPULSE**

**•THE LEFT MULTIFIDUS STABILIZES AND DEROTATES THE SPINE TO SUPPORT THE FUNCTION OF THE RIGHT PSOAS**

•DONTIGNY ©

**•NORMAL GAIT** •FIG. 5

**•SINGLE SUPPORT**

**•AFTER TOE-OFF TENSION STORED IN THE ANTERIOR FASCIA OF THE LEG IS RELEASED**

**•THE CO-CONTRACTION OF THE HAMSTRINGS WITH THE QUADRICEPS PROVIDES LATERAL STABILITY TO THE LEFT KNEE**

**•THE POSTERIOR MOVEMENT OF THE TRUNK FACILITATES THE RIGHT ILIOPSOAS IN BRINGING THE TRAILING LEG FORWARD**

**•THE CONDYLES OF THE KNEE FACILITATE STRAIGHT TRACKING IN THE SWING PHASE**

•DONTIGNY ©

**•NORMAL GAIT** •FIG. 6

**•AFTER POSTERIOR RECOVERY OF THE TRUNK IT AGAIN ACCELERATES ANTERIORLY**

**•PELVIS IS AGAIN SYMMETRICAL AT SINGLE SUPPORT PHASE**

**•TRUNK CONTINUES TO MOVE FORWARD NOW BY FALLING OFF OF THE PERPENDICULAR LEG**

•DONTIGNY ©

**•NORMAL GAIT** •FIG. 7

**•SINGLE SUPPORT**

**•THE LEFT GLUTEUS MAXIMUS, THE LEFT HAMSTRINGS AND LEFT GASTROCNEMIUS STABILIZE THE KNEE IN EXTENSION AND FUNCTION TO DECELERATE AND EASE IMPACT LOADING ON THE CONTRA LATERAL SIDE**

**•KNEE BEGINS TO EXTEND PRIOR TO HEEL STRIKE**

•DONTIGNY ©

**•NORMAL GAIT** •FIG. 8

**•ASYMMETRIC PELVIS**

**•INITIAL DOUBLE SUPPORT**

**•PSIS LOWER ON RIGHT HIGHER ON THE LEFT**

**•SACRUM FLEXED LATERALLY AND ROTATED TO THE RIGHT DRIVING TRUNK ROTATION TO THE RIGHT**

**•COUNTER ROTATION OF THE TRUNK OCCURS PRIOR TO HEEL STRIKE AND DECREASES THE FORCE OF IMPACT LOADING**

**•KNEE FLEXES SLIGHTLY TO ABSORB THE DECELERATION FORCE OF IMPACT LOADING**

•DONTIGNY ©

**•NORMAL GAIT** •FIG. 9

**•WEIGHT LOADING RIGHT**

**•TRUNK DECELERATING**

**•GASTROCNEMIUS AND TOE FLEXORS CONTINUE DECELERATION UNTIL LOADING OCCURS**

•DONTIGNY ©

**•NORMAL GAIT** •FIG. 10

**•TRUNK REVERSAL**

**•THE PIRIFORMIS AND THE SACRAL PORTION OF THE GLUTEUS MAXIMUS WORK TO BRING THE LATERALLY FLEXED AND ROTATED SACRUM BACK TO NEUTRAL**

**•SACRAL ORIGIN OF THE GLUTEUS MAXIMUS ALSO FUNCTIONS TO PULL THE BODY FORWARD UNTIL THE LEG IS PERPENDICULAR**

**•THE RIGHT MULTIFIDUS STABILIZES THE SPINE TO SUPPORT THE FUNCTION OF THE LEFT PSOAS AS IT BRINGS THE TRAILING LEG FORWARD**

•DONTIGNY ©

**•NORMAL GAIT** •FIG. 11

**•TERMINAL DOUBLE SUPPORT**

**•SACRAL MOVEMENT ON AN OBLIQUE AXIS**

**•HIGH PSIS LEFT, LOW RIGHT**

**•AXIS FROM S3 SJJ LEFT TO S1 SJJ RIGHT**

**•OBLIQUE SACRAL MOVEMENT ANTERIOR AT S1 LEFT AND POSTERIOR AT S3 RIGHT**

**•PELVIC STABILIZATION BY THE GLUTEUS MAXIMUS AND GLUTEUS MEDIUS**

•DONTIGNY ©

**•NORMAL GAIT** •FIG. 12

**•SINGLE SUPPORT**

**•PELVIC STABILIZATION IS BY THE SEQUENTIAL CONTRACTIONS OF THE GLUTEUS MAXIMUS, MEDIUS, MINIMUS AND TENSOR FASCIA LATA**

**•TOE-OFF RELEASES TENSION IN THE ANTERIOR FASCIA OF THE TRAILING LEG WHICH FACILITATES THE ACTION OF THE LEFT ILIOPSOAS AND RSVD**

**•THE TIBIAL CONDYLES FUNCTION TO PROVIDE STRAIGHT TRACKING OF THE KNEE ON THE SIDE OF SWING THROUGH AND PROTECTS THE OTHER KNEE FROM TORSION DURING THE HORIZONTAL PELVIC SWING PHASE**

•DONTIGNY ©

**•NORMAL GAIT** •FIG. 13

**•SINGLE SUPPORT**

**•FOLLOWING POSTERIOR RECOVERY THE TRUNK RESUMES ANTERIOR ACCELERATION**

**•PELVIS IS AGAIN SYMMETRICAL AT THE SINGLE SUPPORT PHASE**

**•THE PERONEUS LONGUS PROVIDES STABILITY FOR THE HALLUS AND FOR THE SACROTUBEROUS LIGAMENT**

**•THE GLUTEUS MAXIMUS, MEDIUS, MINIMUS AND THE TENSOR FASCIA LATA STABILIZE THE PELVIS**

•DONTIGNY ©

**•NORMAL GAIT** •FIG. 14

**•SINGLE SUPPORT**

**•THE PERONEUS LONGUS PROVIDES UP TO 18% OF THE STABILITY OF THE SACROTUBEROUS LIGAMENT**

**•ILIAL ORIGIN OF THE GLUTEUS MAXIMUS CONTROLS THE HORIZONTAL PELVIC SWING AND DECELERATES TO DECREASE LOADING**

**•HAMSTRINGS AND GASROC STABILIZE THE KNEE AND DECELERATE**

**•LEFT KNEE EXTENDS PRIOR TO INITIAL CONTACT**

•DONTIGNY ©

**•NORMAL GAIT** •FIG. 15

**•ASYMMETRIC PELVIS**

**•OBLIQUE AXIS**

**•INITIAL DOUBLE SUPPORT**

**•ANY LESION THAT AFFECTS THE SACROILIAC JOINTS AFFECTS NORMAL GAIT !!!**

**•TOE FLEXORS CONTINUE DECELERATION UNTIL LOADING**

•DONTIGNY ©