# Body Mechanics
*by Joseph E. Muscolino | illustrations by Giovanni Rimasti*

> "Perhaps no muscles are more misunderstood and have more dysfunction attributed to them than the psoas muscles. Looking at the multiple joints that the psoas major crosses, and ... it is easy to see why."

# PSOAS MAJOR FUNCTION
*A Biomechanical Examination of the Psoas Major*

### INTRODUCTION

The psoas major is a multijoint muscle that spans from the thoracolumbar spine to the femur. Its proximal attachments are the anterolateral bodies of T12-L5 and the discs between, and the anterior surfaces of the transverse processes of L1-L5; its distal attachment is the lesser trochanter of the femur (Figure 1)[15]. Because the psoas major blends distally with the iliacus to attach onto the lesser trochanter, these two muscles are often described collectively as the iliopsoas. Some sources also include the psoas minor as part of the iliopsoas[5]. Although variations occur for every muscle, including the psoas major, its attachments are fairly clear. What are not entirely clear are the biomechanical effects that the psoas major has upon its attachments, especially upon the spine. Indeed, in this regard, the psoas major is likely the most controversial muscle in the human body.

### MUSCLE BIOMECHANICS

A typical muscle attaches from the bone of one body part to the bone of an adjacent body part, thereby crossing the joint that is located between them (Figure 2). The essence of muscle function is that when a muscle contracts, it creates a pulling force toward its center [14]. This pulling force is exerted on its attachments, attempting to pull the two body parts toward each other. There are also resistance forces that oppose the movement of each of the body parts. Most commonly, this resistance force is the force of gravity acting on the mass of each body part and is equal to the weight of the body part.

If the pulling force of the muscle's contraction is greater than the resistance force, the muscle will contract and shorten, termed a *concentric contraction,* and the body part will move at the joint that is crossed

by the muscle. When a muscle's joint actions are listed in textbooks, it is the muscle's concentric contraction joint actions that are described. Generally, only one of the two attachments moves because its resistance to movement is less than the resistance to movement of the other body part. However, in some cases, the resistance to motion for each of the two body parts is approximately equal and both attachments will move (Figure 3).

The joint action that a muscle can create can be figured out by analyzing the biomechanics of the muscle's pulling force relative to the joint that is crossed. The parameter that needs to be determined is the line of pull of the muscle relative to the axis of motion of that joint. The axis of motion is an imaginary line that generally passes through the joint that is crossed by the muscle. If a muscle's line of pull passes on one side of the joint, it will have the ability to create one joint action; if its line of pull passes on the other side of the joint, it will have the ability to create the opposite (antagonistic) joint action (Figure 4). Given that joint actions are technically motions within a cardinal plane (i.e., sagittal, frontal, or transverse plane), to determine the motion/joint action in each plane, we would need to examine separately the muscle's line of pull relative to the axis for each cardinal plane.
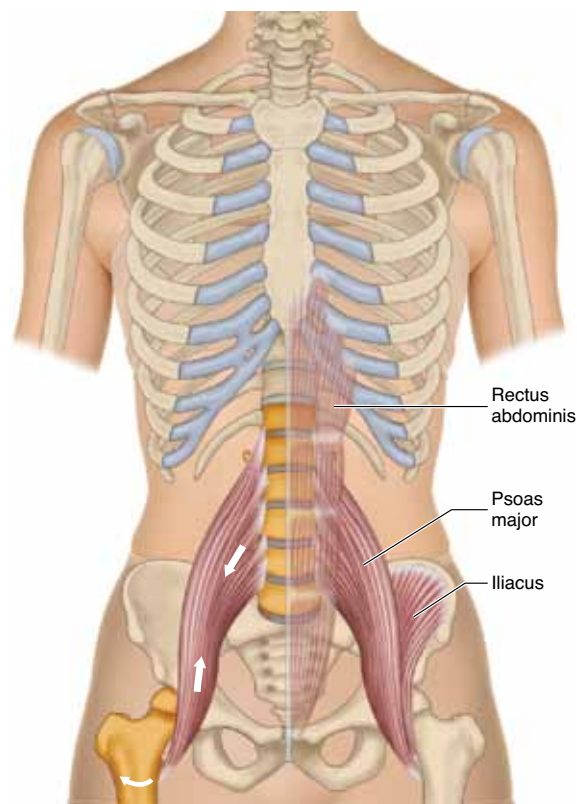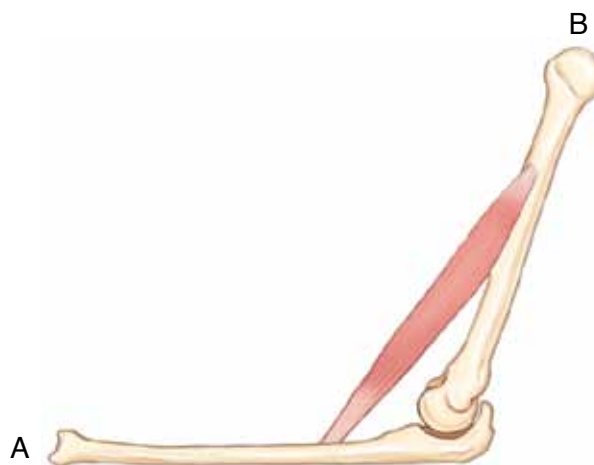


**FIGURE 1**

Anterior view of the psoas major muscles. The left iliacus has been drawn in; and the left rectus abdominis has been ghosted and drawn in. Reproduced with kind permission from Muscolino, J. E., The Muscular System Manual: The Skeletal Muscles of the Human Body (3rd ed.). Mosby of Elsevier.

## Concentric, Eccentric and Isometric Contractions

The resistance force that is created by gravity to movement of a body part is described as an external force because it is generated outside of the body. Other forces, both internal and external, can also provide resistance to the movement of a body part. Examples of internal resistance forces are the contractions of other muscles in our body. Examples of external resistance forces other than gravity are added weights to an exercise, another person pushing/pulling on our body or perhaps a strong wind. When a muscle contracts, its length is determined by the relative strength of the muscle contraction compared to the resistance force.

If the muscle's contraction force is greater than the resistance force, the muscle will contract and shorten, termed a *concentric contraction*. If the muscle's contraction force is equal to the resistance force, the attachments of the muscle will not move, therefore the length of the muscle does not change, and the muscle's contraction is described as an *isometric contraction*. If the muscle's contraction force is less than the resistance force, the muscle will lengthen out as it contracts and its contraction is described as an *eccentric contraction*.



**FIGURE 2**

A typical muscle attaches to the bones of two adjacent body parts, thereby crossing the joint located between them. Reproduced with kind permission from Muscolino, J. E., The Muscular System Manual: The Skeletal Muscles of the Human Body (3rd ed.). Mosby of Elsevier.
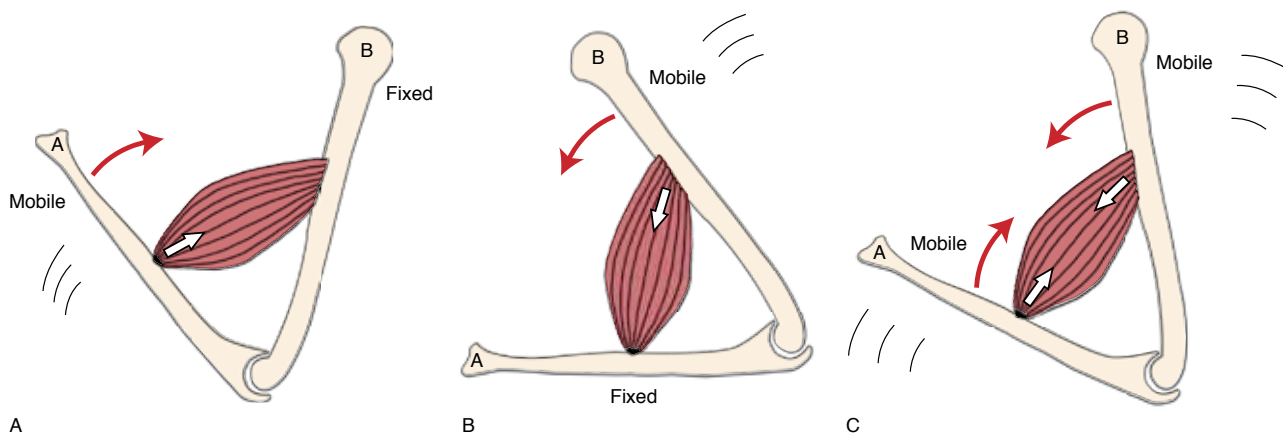
## FIGURE 3
Concentric contractions of a muscle. **A**, Attachment "A" moves. **B**, Attachment "B" moves. **C**, Both attachments "A" and "B" move.
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## FIGURE 4
Right lateral view showing that a muscle's line of pull relative to the axis of the joint determines its joint action. **A**, Flexion of the thigh at the hip joint. **B**, Extension of the thigh at the hip joint. Note: The axis is represented by the red dot.

### BIOMECHANICS OF THE PSOAS MAJOR

The psoas major is first and foremost a muscle of the hip joint[5, 9, 12]; therefore, to determine its actions, we need to compare its line of pull at the hip joint in each of the three cardinal planes. Standard actions at the hip joint are considered to involve movement of the distal attachment—in other words, the thigh. These actions occur when the lower extremity is in what is known as "open-chain" position, with the distal segment, the foot, free to move. However, if the foot is planted on the ground and the lower extremity is in closed-chain position, the pelvis moves at the hip joint instead; when the proximal attachment moves instead of the distal attachment, this is called a reverse action[14]. Therefore, a thorough examination of the psoas major at the hip joint involves consideration of its standard and reverse actions at that joint.

However, the psoas major is more complicated because it also crosses the lumbar spine, therefore we need to also examine its line of pull across the spine. As with

the hip joint, the spine also allows motion in all three cardinal planes, so our examination of the psoas major must also consider the possible spinal actions in each of the three cardinal planes. What further complicates a clear understanding of the psoas major's actions is the fact that the lumbar spine is not monolithic. There are many joints within the lumbar spine, each with its own axis of motion; therefore, each of these joints must be considered separately. And finally, interposed between the spinal and femoral attachments of the psoas major is the pelvis. Therefore, the pull of the psoas major can affect the posture of the pelvis. Changing the posture of the pelvis can then change the posture of the lumbar vertebrae, which can change the line of pull of the psoas major relative to the axes of motion of the lumbar spinal joints and therefore possibly change the action of the psoas major.

All of these factors help to explain why the psoas major can be so challenging to understand. Following is an examination of the functions of the psoas major

at both the hip and spinal joints. In our discussion, we will consider some of the competing assertions for psoas major function by many of the leading authors in the field of kinesiology, and attempt to explain and perhaps resolve many of the reasons for the controversy regarding psoas major function.

### PSOAS MAJOR HIP JOINT ACTIONS

The hip joint is a triaxial joint that allows motion in all three cardinal planes. Therefore, we can examine the effect of the psoas major in each of the three cardinal planes. Further, we need to consider the open-chain motions of the thigh relative to the pelvis at the hip joint and the closed-chain motions of the pelvis relative to the thigh at the hip joint.

**Sagittal Plane**  In the sagittal plane, there is little or no controversy over the *potential action* of the psoas major at the hip joint. It clearly crosses the hip joint anteriorly, passing anterior to the mediolateral axis of motion (see Figure 4A); therefore, it flexes the hip joint. If we are in an open-chain position, the thigh flexes at the hip joint. If we are in a closed chain position, the pelvis anteriorly tilts at the hip joint (Figure 5).

## Strength of a Muscle's Contraction

Determining what joint action a muscle can create is a factor of the line of pull of the muscle relative to the joint's axis of motion. However, other factors must be looked at to determine the strength that the muscle will have when creating this motion. These factors can be divided into internal and external factors. The major internal factor is the internal strength of the muscle, which is essentially determined by the number of sarcomeres, or more specifically the number of myosin-actin cross-bridges within the muscle. Because the architectural arrangement of the muscle fibers affects this equation (whether the muscle is pennate or non-pennate in arrangement), the measure of a muscle's internal strength is effectively determined by the physiological cross sectional area of the muscle. The external factor that determines a muscle's strength is its leverage force, or moment arm, at the joint crossed. In effect, the farther the muscle's line of pull is from the axis of motion, the greater is the leverage/moment arm, and therefore the stronger is the effect of the muscle's contraction force; the closer the line of pull is to the axis, the weaker is the muscle's contraction force. A moment arm is the measure of the distance from the axis of the joint along a line that meets the muscle's line of pull at a perpendicular angle (see Figure 6).

**Sagittal Plane: Thigh Flexion**  All sources concur that the psoas major is a flexor of the hip joint. In fact, most sources state that hip flexion is its primary function [3, 5, 9]. Stuart McGill goes as far as to state "The role of the psoas is purely as a hip flexor." [12]. And many sources go on to describe the psoas major's hip flexion role rather effusively. Janet Travell and David Simons described the psoas major as a "major muscle of hip flexion"[27]; and its hip flexion role has been described by others as "strong"[5], "powerful"[6], or "dominant"[19]. Carol Oatis specifically points out that the psoas major is a "strong hip flexor" because it has a large physiological cross sectional area[20]. Sometimes authors discuss the psoas major along with the iliacus as the iliopsoas. In these cases, it can be difficult to determine what to ascribe to the psoas major versus the iliacus, but the iliopsoas as a whole is often stated to be the prime mover (in other words, the most powerful mover) of hip joint flexion[4].

Although no source contests the ability of the psoas major to create flexion at the hip joint, not every source is as convinced of the power of its hip flexion ability. One study asserts that the psoas major's hip flexion is relatively weak at the beginning and end ranges of motion, and that it is strongest between 45 and 60 degrees of flexion[31]. In fact, many sources believe that the primary role of the psoas major is not to actually move the bones at the hip joint by concentrically contracting, but rather to stabilize the bones of the hip joint by isometrically contracting[2, 21, 26]. They point out that the moment arm of the psoas major is smaller than the moment arm for most of the other hip flexors because the muscle's line of pull passes so close to the mediolateral axis of motion (Figure 6)[19, 20].

Therefore it would make sense that these other hip flexor muscles with greater moment arms would more efficiently pull the hip joint into flexion. Evan Osar believes that the major role of the psoas major at the hip joint is to stabilize and center the head of the femur in the acetabulum as other hip flexors contract[21]. He uses the term "centration" to describe this idea. Sean Gibbons also believes that the primary role of the psoas major at the hip joint is stability. He points out that the fiber architecture of the psoas major is not fusiform; rather, it is unipennate[2, 31]. Pennate muscles are designed to produce greater force over a shorter distance, whereas nonpennate muscles are designed to produce a greater range of motion. Therefore, "…the ability of the muscle to shorten is less than believed. This calls into question its efficiency as a hip flexor." [2].

However, it should be noted that these comparative flexion moment arms are at anatomic position. If the thigh were first in flexion, the moment arm of the psoas major would increase, and therefore its strength and
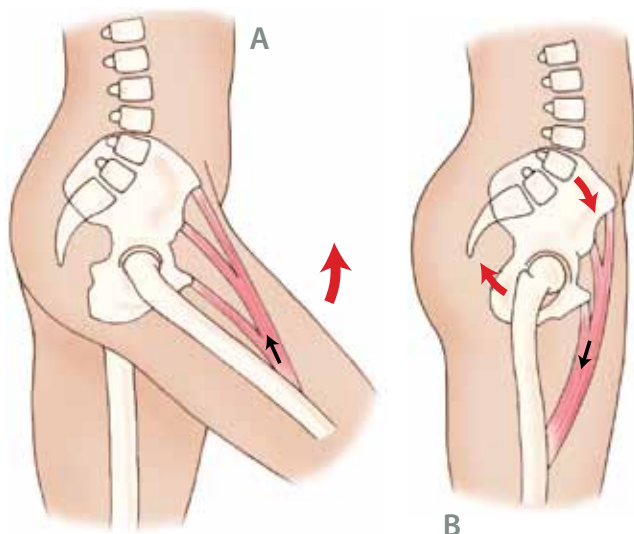
**FIGURE 5**

Flexion at the hip joint. **A**, Open-chain flexion of the thigh at the hip joint. **B**, Closed-chain anterior tilt of the pelvis at the hip joint. Reproduced with kind permission from Muscolino, J. E., Kinesiology: The Skeletal System and Muscle Function (2nd ed.). Mosby of Elsevier.

potential role in creating flexion motion at the hip joint would increase (as previously mentioned, a study found the psoas major to be strongest between 45 and 60 degrees) (Figure 7).

What to conclude from this discussion? There is no doubt that the psoas major's line of pull is anterior to the hip joint and that its contraction creates a force of flexion at the hip joint. The only question seems to be whether this hip flexion force is more important for motion or for stabilization. These concepts, however, do not need to be mutually exclusive because a muscle can have a stabilization role as well as a role in motion.

Generally, it is true that deeper muscles at a joint tend to function more for stabilization than for motion, and looking at the psoas major's location does show it to be a deep muscle. Further, given all the other hip flexor muscles that exist with greater moment arms, it is likely that they would more efficiently act toward creating hip flexion motion. This all points to the psoas major acting primarily as a stabilizer of the hip joint when we are in anatomic position and/or when lesser hip flexion force is necessary. But the psoas major is a large and powerful muscle and it would make sense that if a greater hip flexion contraction force were needed, then the psoas major would be recruited to assist in the creation of this motion. This is especially true if the hip joint were already flexed, because of the increased moment arm leverage.

**Sagittal Plane: Pelvic Anterior Tilt**  Regarding closed-chain sagittal plane motion of the pelvis at the hip joint, the line of pull of the psoas major would pull the pelvis into anterior tilt at the hip joint [14, 19, 25, 29]. This assumes that the pelvis is fixed to the trunk as the trunk is pulled anteriorly. Closed-chain position in the lower extremity usually occurs when the foot is planted on the ground. For this reason, psoas major closed-chain function is especially important for standing posture. If the baseline tone of bilateral hip flexor musculature, including the psoas major, is tight, it will create an increased anterior tilt of the pelvis [4, 5, 19]. Note: This will have important ramifications for the spine when discussing the effects of the psoas major upon the spine later in this article.

**Frontal Plane**  Within the frontal plane at the hip joint, if the open-chain standard action is abduction of the thigh at the hip joint, the closed-chain reverse action is depression of the pelvis at the hip joint (Figure 8) [14, 19].

**Frontal Plane: Thigh Abduction**  The frontal plane action of the psoas major may be more controversial than the sagittal plane activity, but is not debated near as often because it is far less important due to its weak frontal plane leverage force. In fact, many prominent sources such as Gray's Anatomy, Don Neumann and Stuart McGill do not even address the psoas major in the frontal plane [12, 19, 29]. When stated, most sources claim that the psoas major is an abductor of the thigh at the hip joint [8, 21, 25, 27]. However, occasional sources claim it to be an adductor [6].

To understand this debate and determine whether the psoas major is an abductor or adductor, we need to examine its line of pull relative to the anteroposterior axis of frontal plane motion at the hip joint (Figure 9). In anatomic position (Figure 9A), the line of pull of the psoas major may actually pass medial to the axis of motion, therefore, it would seem that the psoas major is an adductor. However, if the thigh is first abducted (Figure 9B), then we see that its line of pull moves to the lateral side of the axis and the psoas major becomes an abductor. In fact, Travell and Simons state that the psoas major only assists abduction after abduction has been initiated by other muscles [27]. Interestingly, if the thigh is first laterally rotated (Figure 9C), we see that the lesser trochanter moves laterally and the psoas major's line of pull also moves lateral to the axis creating/increasing its ability to perform abduction of the thigh at the hip joint. This is an excellent example of a muscle whose action changes depending on the angle of the joint.

Regardless of whether the psoas major is in position to perform abduction or adduction, given how small

the moment arm is, it would not be able to generate much strength to contribute to the joint motion. In fact, because its line of pull passes pretty much directly over the axis, most of the pull of the psoas major in the frontal plane would contribute toward compression, and therefore stability, by pulling the head of the femur into the acetabulum.

**Frontal Plane: Pelvic Depression** If the psoas major is an abductor, then the closed-chain frontal plane motion of the pelvis at the hip joint would pull the same-side pelvis into depression at the hip joint; this assumes that the pelvis is fixed to the trunk as the psoas major contracts. (Note: If the pelvis is not fixed to the trunk, the psoas major will pull the trunk into lateral flexion at the spinal joints as discussed later in this article.) However, given that the line of pull of the psoas major passes pretty much directly over the hip joint, the psoas major would seem to be an effective stabilizer of the pelvis on the femur at the hip joint in the frontal plane.

**Transverse Plane** Within the transverse plane at the hip joint, if the open-chain standard action is lateral rotation of the thigh at the hip joint, the closed-chain reverse action is contralateral rotation of the pelvis at the hip joint (Figure 10)[14, 19].

**Transverse Plane: Thigh Lateral Rotation** Within the transverse plane, the function of the psoas major has been claimed to be both medial rotation and lateral rotation. However, it seems that no major source currently describes it as a medial rotator. Tom Myers states that "…most agree that it produces lateral rotation, though arguments can be made (with which this author disagrees) that it could produce medial rotation of the femur."[16] Gray's Anatomy states "Electromyographic studies do not support the common view that psoas major acts as a medial rotator of the hip joint…"[29].

Instead, most sources agree that it is a lateral rotator [1, 6, 8, 15, 20, 21, 25, 27, 28, 29, 30]. But many of these sources state that its lateral rotation ability is weak [12, 20, 27, 29]. Because of its weak rotation ability, Tom Myers describes the psoas major as a "non-rotator."[16]. John Basmajian went so far as to say that "The controversy as to whether it is a medial or a lateral rotator should be abandoned because, in fact, it is only weak lateral rotator."[1]. This is backed up by the fact that a number of sources do not even discuss it transverse plane rotation ability[5, 9, 19].

**Transverse Plane: Pelvic Contralateral Rotation** Regarding closed-chain transverse plane motion of the pelvis at the hip joint, the line of pull of the psoas major would pull the pelvis into opposite-side (contralateral) rotation at the hip joint (as seen in Figure 10B) if the pelvis were fixed to the trunk as the psoas major contracts[15]. (If the pelvis were not fixed to the trunk, then the trunk would contralaterally rotate at the spinal joints as discussed later in this article.)
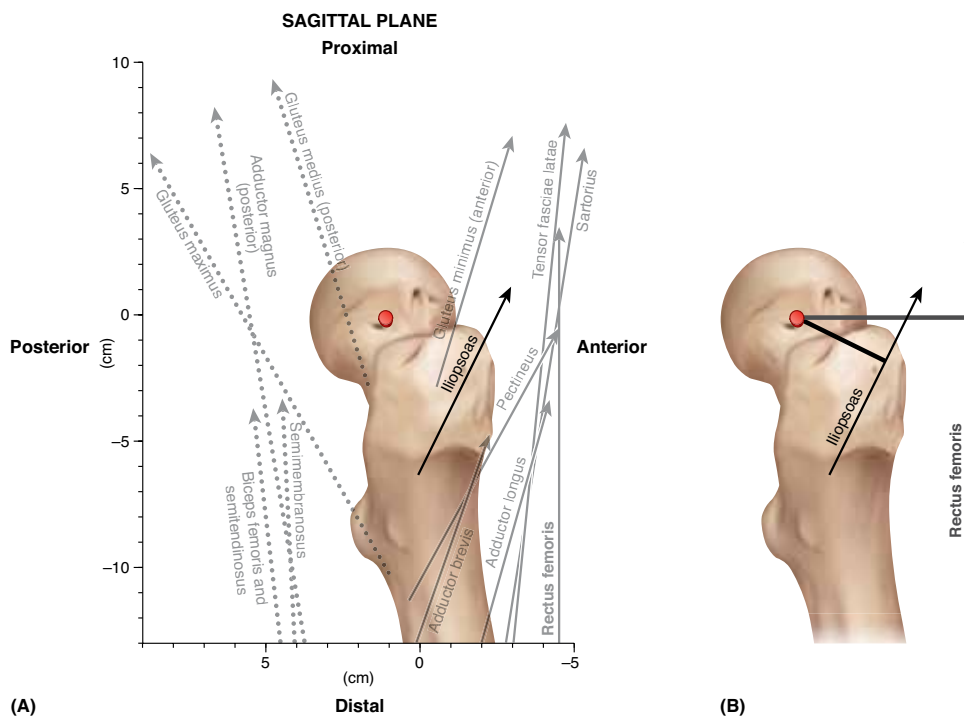


**FIGURE 6**

Right lateral view demonstrating lines of pull for flexors and extensors at the hip joint. A, Flexors shown with solid lines; extensors shown with dotted lines. B, Moment arms drawn in for the iliopsoas (psoas major) and the rectus femoris. Reproduced with kind permission from Joseph E. Muscolino. Modeled from Neumann, Kinesiology of the Musculoskeletal System: Foundations for Rehabilitation (2nd ed.). Mosby of Elsevier.

## Movement or Stability?

As stated, determining the action of a muscle is done by comparing the line of pull of the muscle relative to the axis of motion of the joint crossed. If the muscle passes on one side of the axis, it will create one motion; if it passes on the other side, it creates the opposite (antagonist) motion. And measuring how far the muscle's line of pull is from the axis gives us the moment arm, which gives us the leverage strength for creating the motion. However, muscle contractions are not only important for creating motion. The pulling forces of musculature are also important for stabilizing the joint. This can be done when the muscle creates a compression force that pulls one bone of the joint into the other; this occurs when the line of pull of the muscle passes close to or through the axis of motion for the joint, as seen in Figure 9A.

### PSOAS MAJOR SPINAL JOINT ACTIONS

Similar to the hip joint, the spine also allows motion in all three cardinal planes. Therefore the effect of the psoas major must be examined separately in each of these planes. The frontal and transverse plane spinal motions are relatively straight forward, so we will briefly discuss these first. We will then tackle the most controversial aspect of psoas major function, its effect upon the spine in the sagittal plane.

**Frontal Plane** The frontal plane spinal action of the psoas major is fairly clear; it crosses the spinal joints laterally, so unilateral contraction would clearly create a pulling force upon the spine into lateral flexion to that side. This is supported by many sources [3, 5, 7, 15, 19, 20, 23, 25, 30] and can be seen by comparing the line of pull of the muscle relative to the axes of motion located at the center of each disc (Figure 11). Carol Oatis goes so far as to state that the psoas major is an "…effective lateral flexor of the trunk." [20]. However, there are some sources that play down the psoas major's role in spinal lateral flexion. Shirley Sahrmann states that "…the lateral flexion moments…are small…" and Gray's Anatomy states that "…electromyography does not support… lateral flexion." [25, 29]. What to conclude? Although the spinal moment arm leverage of the psoas major in the frontal plane is nowhere near as large as more laterally located muscles such as the quadratus lumborum or the lateral fibers of the abdominal wall muscles (external and internal abdominal obliques), given the large physiological cross section of the psoas major it should have sufficient strength to have a moderate or perhaps even strong contribution to lateral flexion motion.

**A**



**B**



50°
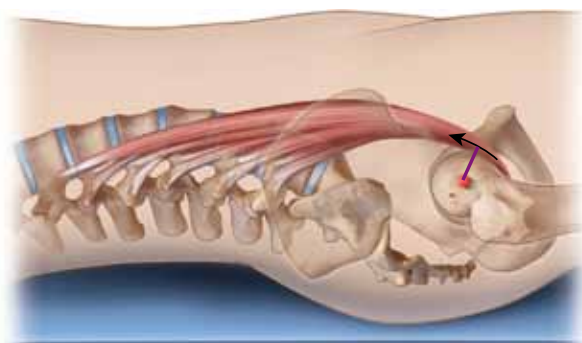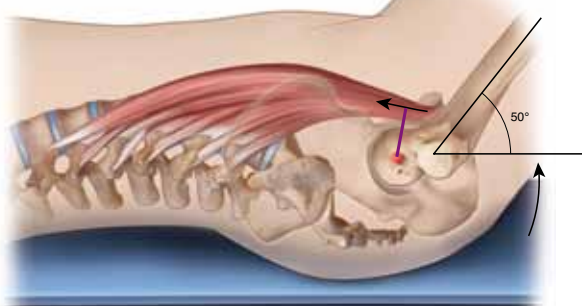
### FIGURE 7

The moment arm and therefore leverage force for thigh flexion of the psoas major increases when the thigh is first flexed. **A**, Anatomic position. **B**, 50 degrees of flexion. Reproduced with kind permission from Joseph E. Muscolino.

**Transverse Plane** The role of the psoas major in creating spinal motion within the transverse plane does not seem to be strong. Most sources do not even mention its ability to rotate the lumbar spine. Of the few sources who do, it is stated as a contralateral rotator [7, 19]. This would fit with the usual reverse action at the hip joint of lateral rotators of the thigh being contralateral rotators of the pelvis (see Figure 10) [14], only instead of contralaterally rotating the pelvis such that its anterior surface comes to face the opposite of the body, the lumbar vertebrae are rotated so that their anterior surfaces come to face the opposite side of the body. Perhaps the reason that the transverse plane motion of the spine is not commonly cited is that its leverage around the vertical axis for spinal rotation is small. Don Neumann states "Little, if any, leverage exists for axial rotation." [19]. However, it is worth adding that even if the psoas major has little leverage to axially rotate the trunk at the lumbar spinal joints, given its lateral rotation ability at the hip joint (discussed previously), its reverse action of contralaterally rotating the pelvis at the hip joint would
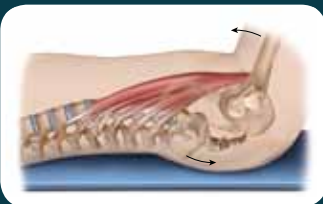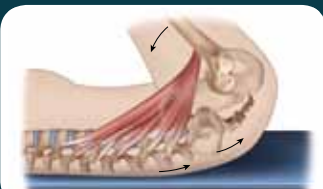
## Open-Chain Spinal Motion by the Psoas Major

Motions of the spine by the psoas major are usually considered to be closed chain-motion motions because most commonly the (proximal) spine is mobile and moves toward the (distal) thighs, which are fixed. However, it is possible to conceive of the psoas major moving the spine in open-chain position of the lower extremities in which the thighs are the mobile attachments, and the upper spine is the fixed attachment. If, for example, the client is lying supine and contracts the psoas majors bilaterally, the thighs will flex toward the pelvis at the hip joints (Figure A). As the thighs continue to flex, via the concept of femoropelvic rhythm ([14]), the pelvis will then begin to posteriorly tilt at the lumbosacral joint (Figure B). As the thighs continue to flex and the pelvis continues to posteriorly tilt, because the lumbosacral joint only allows a few degrees of motion, the force of the psoas major contraction will continue up into the lumbar spine, sequentially moving each lumbar vertebra into flexion relative to the vertebra that is superior to it (Figure C). Thus we have the lower lumbar spine mobile and flexing relative to the fixed upper lumbar spine.

contribute to turning the trunk to face the opposite side of the body (as long as the trunk stays fixed to the pelvis). In this case, the axis for rotation would be at the hip joint instead of the spine.

**Sagittal Plane** Within the sagittal plane, the question is whether the psoas major creates flexion or extension of the lumbar spine.

**Overview of the Controversy** Of all of the psoas major's functions, its effect upon the lumbar spine in the sagittal plane is by far the most controversial. Evaluating its pull on the lumbar spine in the sagittal plane is complicated by the fact that there is a different (mediolateral) axis of motion for each of the lumbar spinal joints. It is further complicated by the fact that the lumbar spine curves within the sagittal plane; and whether the lumbar spine has a normal lordotic curve, a decreased (hypolordotic) curve, or an increased (hyperlordotic) curve, can change the muscle's line of pull relative to each of these axes. The psoas major can directly affect the degree of the lumbar curve because it crosses these joints; and it can indirectly affect the lumbar curve by changing the posture of pelvic tilt across the hip joint. And, certainly, the degree of lordotic curve is affected by whether or not the person is in anatomic position or their spine is first flexed or extended. As a result, the action of the psoas major at one lumbar spinal joint might be different than its action at another lumbar spinal joint; and each of these actions might change as the position of the lumbar spine changes. The psoas major is also a large muscle that can be considered to have upper and lower fibers, as well as anterior and posterior fibers. Consequently, many sources divide the psoas major into upper and lower parts; and others divide it into anterior and posterior parts.

**Flexion versus Extension of the Spine** Scanning the literature, the controversy is immediately apparent. Numerous sources describe sagittal plane spinal function of the psoas major by stating that it can either "flex," "bend," "pull the trunk anteriorly," or "raise it from a supine position"[3, 4, 6, 7, 9, 15, 16, 19, 20, 24, 27, 29, 30]. But in many of these cases, whether flexion of the "trunk" refers to flexion of the lumbar spinal joints or instead refers to anterior tilt of the pelvis at the hip joints (with the lumbar spine moving along with the pelvis) is not clear because some references state that it flexes/bends/pulls the trunk anteriorly, but they also state that it increases lordosis[6, 7, 9]. This might seem somewhat contradictory because flexion of the lumbar spine essentially decreases lordosis because lordosis is a curve of extension[14, 27]. Other sources state that the psoas major can extend the lumbar spine[2, 4, 19, 20, 23, 25, 27]. How to reconcile these results?

Effectively, we need to return to the fundamental understanding of how a muscle functions: it creates a line of pull relative to the axis of a joint. If the psoas major has a line of pull that is anterior to a lumbar spinal joint, that line of pull will cause flexion at that joint; if the psoas major has a line of pull that is posterior to a lumbar spinal joint, that line of pull will cause extension at that joint. So let's examine the line of pull of the psoas major at the lumbar spine, or stated more accurately, let's examine the psoas major's lines of pull relative to the multiple lumbar spinal joints.
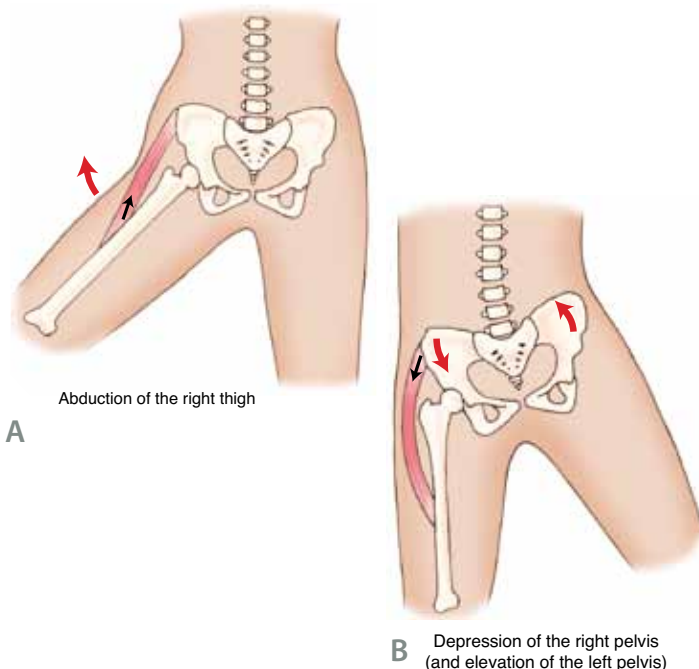
**Upper versus Lower Fibers** Figure 12 shows a lateral view of the psoas major and lumbar spine. Although there is no exact definition, a "neutral pelvis and spine" posture in the sagittal plane when in anatomic position occurs when the sacral base angle is approximately 30 degrees[14, 19]. The sacral base angle is determined by measuring the angle formed by the intersection of a line drawn along the top of the sacral base and a horizontal line. In neutral position spine, we can see that the psoas major passes anterior to some of the axes and posterior to others; therefore, the psoas major can create both flexion and extension of the lumbar spine. Looking more closely, we see that, on the whole, it passes anterior to the lower lumbar spinal joints and posterior to the upper lumbar spinal joints. For this reason, many sources state that the psoas major flexes the lower lumbar spine and extends the upper lumbar spine[2, 9, 19, 20, 24, 25, 25]. Tom Myers states the opposite: that the psoas major extends the lower lumbar spine and flexes the upper lumbar spine. However, he adds that this is clinical speculation and not backed up by evaluation of the mechanical axes[16, 17].

Myers does add a fascinating explanation for why the psoas major is so capable of having differing lines of pull for its upper versus lower fibers. He notes that the psoas major is actually a triangular muscle, not a fusiform muscle as it appears at first glance[17]. If a muscle is triangular in shape, the fibers are not parallel; instead they have different directions and therefore differing lines of pull. Figure 13 demonstrates the psoas major of a quadruped in which we can clearly see the triangular shape. An appreciation of this triangular shape was lost when we stood up and became bipedal because the more superficial, longer, upper fibers now cover over the deeper, shorter, lower fibers. It is worth pointing out that in a quadruped, not only is the triangular shape readily apparent, but the moment arm leverage for the psoas major is much greater than in our bipedal stance.

**Altering the Lordotic Curve** It must be kept in mind that Figure 12 showed a neutral spine in anatomic position. But what happens to psoas major function if we alter the degree of lordosis? Figure 14A shows a decreased sacral base angle with a corresponding decreased lordotic curve; Figure 14B shows an increased sacral base angle with a corresponding increased lordotic curve. Comparing Figures 14A and B with Figure 12, we notice that as the lumbar lordosis decreases, the over all line of pull of the psoas major moves farther anteriorly relative to the axes; and as the lumbar lordosis increases, the over all line of pull of the psoas major moves farther posteriorly relative to the axes. This means that the psoas major



Abduction of the right thigh

**A**

**B** Depression of the right pelvis
(and elevation of the left pelvis)

**FIGURE 8**

Frontal plane motion at the hip joint. **A**, Open-chain abduction of the thigh at the hip joint. **B**, Closed-chain depression of the same-side pelvis at the hip joint. Reproduced with kind permission from Muscolino, J. E., Kinesiology: The Skeletal System and Muscle Function (2nd ed.). Mosby of Elsevier.



**A**

**B**

**C**
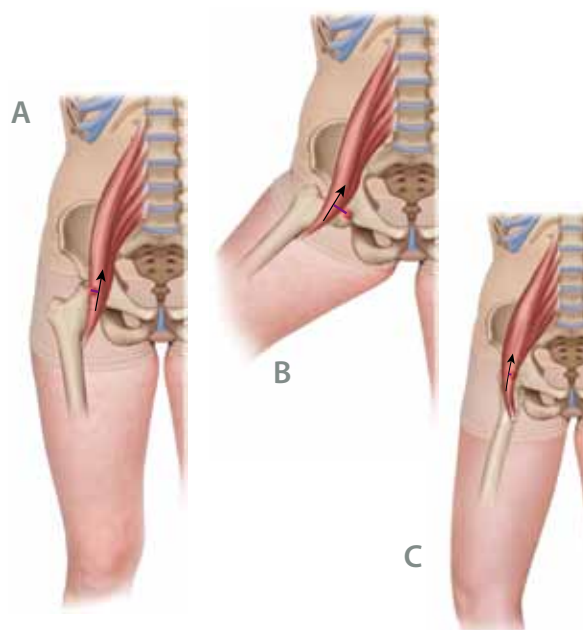
**FIGURE 9**

Anterior view of the psoas major depicting its frontal plane axis (represented by the red dot) and moment arm in various positions. **A**, Anatomic position. **B**, Thigh abduction. **C**, Thigh lateral rotation. Reproduced with kind permission from Joseph E. Muscolino.

flexion capability increases (and its extension capability decreases) as the curve of the spine decreases; and its extension capability increases (and its flexion capability decreases) as the curve of the spine increases. For this reason it is not simple enough to just look at a muscle when the body is in anatomic position. Muscle actions often change as we change the angles of our joints. Indeed, many sources discuss the psoas major's variable ability to flex or extend the spine based on the degree of lordosis [10, 23, 25, 27]. Ironically, the degree of lordosis itself is based on the sacral base angle, and all hip flexors, including the psoas major, if tight, will increase anterior pelvic tilt and therefore increase lumbar lordosis [4, 8, 14, 19]. Therefore, the psoas major affects the lumbar spine both directly by crossing its joints, and indirectly by affecting the posture of the pelvis.

Figure 15 depicts a scenario in which the person's spine is not in anatomic position. In this scenario, the person is doing a curl-up. Similar to Figure 14A, we see that the flexion capability of the psoas major increases compared to anatomic position as the person curls upward. There are many sources that describe varying sagittal plane capability of the psoas major depending on the position of the body or the activity in which it is being engaged [6, 9, 20, 27]. Engagement of the psoas major during sit-ups, crunches, and curl-ups has been especially well studied and documented by many sources [4, 15, 19, 20, 27].

**Anterior versus Posterior Fibers**   There is another distinction regarding the psoas major that can be made. Not only can we look at the psoas major as having upper and lower parts, we can also divide it into anterior and posterior parts. The vertebral body and disc attachments comprise the anterior part; the transverse process attachments comprise the posterior part. Figure 16 separates the anterior versus posterior fibers at the L3-L4 level in relation to the axis of motion at the L4-L5 joint level. We can see that the anterior fibers bias toward crossing the joint anteriorly and would therefore create flexion; and the posterior fibers bias toward crossing the joint posteriorly and would therefore create extension. For this reason, many sources feel that dividing the psoas major anteriorly/posteriorly is valid [2, 7, 24]. Indeed, Gibbons reports that in "…a cadaver dissection study of 24 cadavers, all specimens had a separate nerve supply for the anterior and posterior fasciculi…" He then goes on to state: "In light of this, PM (psoas major) should be considered as two distinct parts: anterior and posterior." [2]

**Psoas Paradox**   So far, analyzing the effect of the psoas major on the lumbar spinal joints has been very straight-forward and direct: compare the line of pull relative to the axis at each joint level and we will have the action of the psoas major at that joint. Unfortunately, this approach might be overly simplistic because the effect of the psoas major cannot necessarily be isolated locally. What occurs at one lumbar spinal joint level might have an effect on nearby joint levels. Looking at the body from this perspective might explain some of the seemingly contradictory effects of the psoas major upon the spine. If we look at the pull of the psoas major at the lower lumbar spinal joints, we see that it crosses anteriorly and therefore should create spinal flexion at the lower lumbar region (see Figure 12). This would imbalance the center of weight of the body anteriorly.



A

Lateral rotation of the right thigh

B

Left (contralateral) rotation of the pelvis
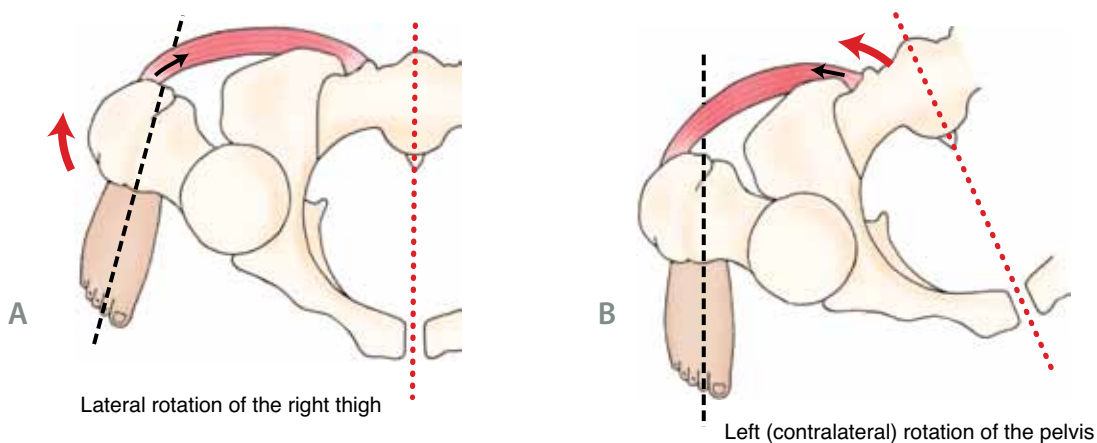
**FIGURE 10**

Transverse plane motion at the hip joint. **A**, Open-chain lateral rotation of the thigh at the hip joint. **B**, Closed-chain contralateral rotation of the pelvis at the same-side hip joint. Reproduced with kind permission from Muscolino, J. E., Kinesiology: The Skeletal System and Muscle Function (2nd ed.). Mosby of Elsevier.

If the nervous system wants to maintain the center of weight of the upper trunk, neck and head balanced over the pelvis, for example so that the eyes and inner ears are level to perceive the world (this is known as the "righting reflex"), it would order other musculature to compensate by creating extension of the upper lumbar region so that the center of weight of the body is brought back posteriorly to be balanced over the pelvis. Therefore, even without a strong ability of the psoas major itself to create spinal extension, and Travell and Simons report that the psoas major's contribution toward extension is extremely weak[27], the response of the body might be to engage other musculature to extend the upper lumbar spine.

This compensation is known as the "psoas paradox" or referred to as "paradoxical lumbar lordosis (lumbar extension)" and has been cited by numerous sources as a sagittal plane effect of the psoas major upon the spine [9, 11, 15, 20, 27]. Oatis makes the point though that this requires the person to have a flexible upper lumbar spine that can move into extension. Otherwise, the person might end up with a decreased lumbar lordosis and a forward lean to their posture, which would be yet another possible effect of the psoas major[20]. The psoas paradox helps to resolve much of the controversy over the psoas major's effect upon the spine and emphasizes the importance of looking at the bigger picture of muscle coordination patterns body-wide.

**Stabilization of the Spine**  Thus far, by examining the lines of pull of the psoas major, it is clear that it can create flexion and extension of the lumbar spine. But because the psoas major is so close to the spine, its moment arms for these motions are small compared to other musculature such as the rectus abdominis anteriorly for flexion, or the erector spinae posteriorly for extension. Regarding the argument over whether the psoas major's role is spinal flexion or extension, Nancy Hamilton wisely states: "…it seems likely that the differences are not of great importance. Frequently, when there is lack of agreement regarding movement, one may safely assume that the true function of the muscular contraction, with reference to the joints in question, is more likely to be stabilization or balance than purposeful movement."[5].

This view that the psoas major acts primarily to stabilize the spine is shared by many others[2, 12, 19, 21, 25, 26, 29]. Neumann states that the psoas major is "…neither a dominant flexor nor extensor of the lumbar region, but rather a dominant vertical stabilizer of the region." [19]. Brunnstrom's states that muscles close to the spine act like guy ropes supporting an upright pole. "When the pole starts to tip, the extension of the ropes on the
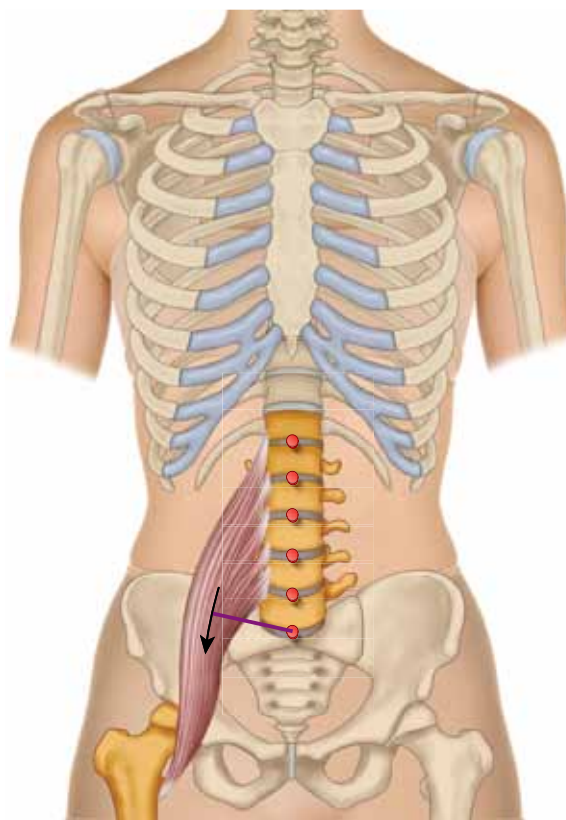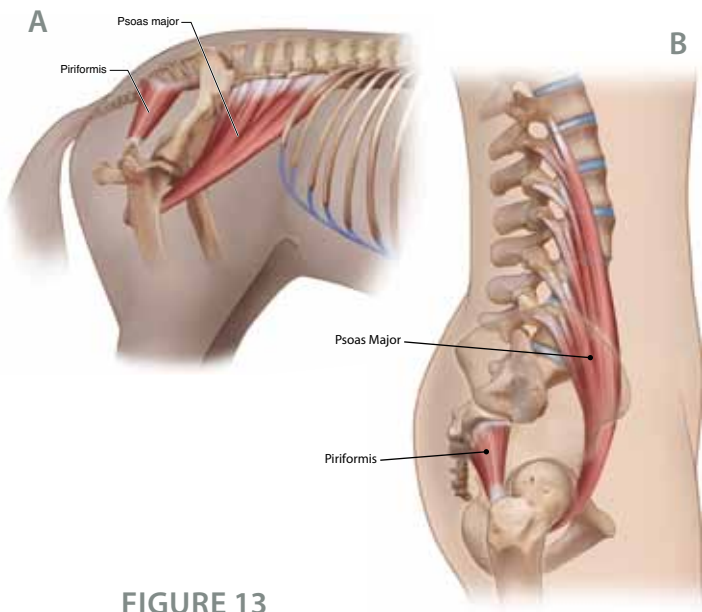


**FIGURE 11**

The frontal plane line of pull of the psoas major clearly passes lateral to the anteroposterior axes of motion at the lumbar spinal joints. Note: The axes have been drawn in with red dots, and the moment arm for the L5-S1 joint has been drawn in. Reproduced with kind permission from Joseph E. Muscolino. Modeled from Muscolino, J. E., The Muscular System Manual: The Skeletal Muscles of the Human Body (3rd ed.). Mosby of Elsevier.
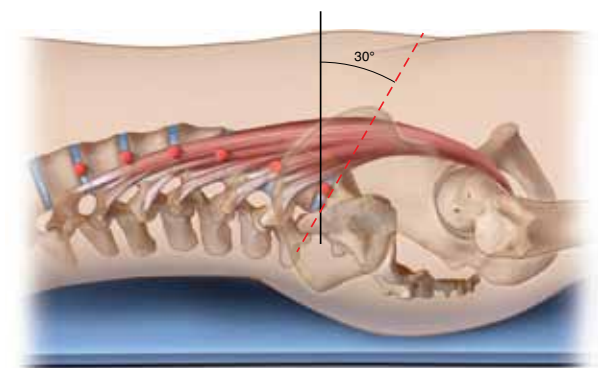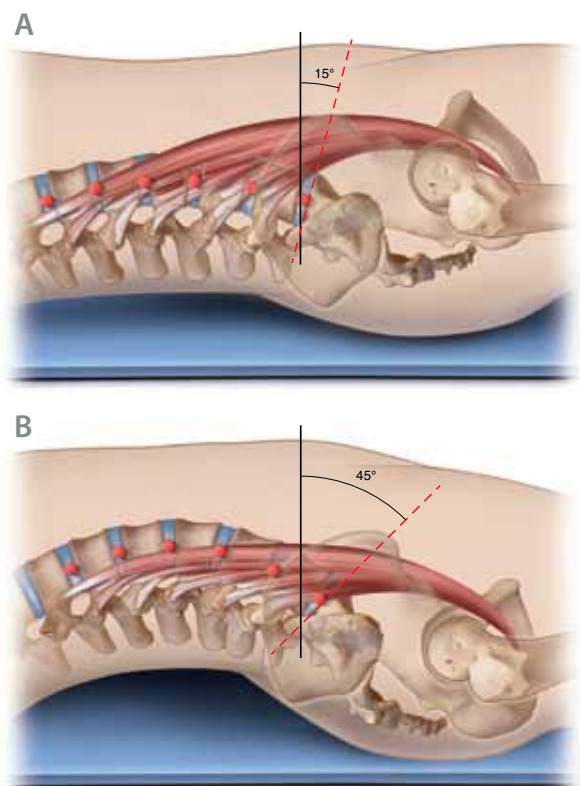


**FIGURE 12**

Right lateral view of the psoas major with a neutral pelvis/spine posture. The axes of motion at the joints are represented by red dots.

**FIGURE 13**

The triangular shape of the psoas major is much more apparent in a quadruped (A) than in a person (B, biped). Reproduced with kind permission from Joseph E. Muscolino. Modeled from Myers, T. (1998). Poise: Psoas-Piriformis Balance. Massage Magazine, March/April, Figure 5B, page 77.



**FIGURE 14**

Lateral views of the psoas major with various degrees of lumbar lordosis. **A**, hypolordotic curve. **B**, Hyperlordotic curve. The axes at the joints are represented by red dots. Note the change in lines of pull of the psoas major as the degree of lordosis changes.

opposite side increases."[28].

The effectiveness of the psoas major as a stabilizer can be validated by noticing that much of its mass crosses either extremely close to or directly over the axes of motion (see Figure 12). Therefore, contraction of the psoas major would create an axial compression that would act to stiffen and stabilize the lumbar spine. Some sources assert that the importance of the psoas major as a stabilizer is specifically linked to hip flexion[2, 12]. Also, the fact that the psoas major is unipennate in design (as mentioned previously) further supports its role as a stabilizer[2, 31].

**Stabilization and Compression of the Spine**   Healthy functioning of a joint demands that the joint is mobile *and* stable. Therefore, motion is not the only importance of a muscle. However, this fact can be easily overlooked because muscle function is usually stated by listing the concentric movement actions of the muscle, not the isometric stabilization contraction functions. Recently, though, with the advent of Pilates and core strengthening in general, the awareness and appreciation of spinal stability has increased. In this regard, the psoas major likely plays an important role.

Some sources are concerned though about the effect upon the spine of psoas major compression/stabilization. Compressing the lumbar spine means compression of the disc joints, with the physical stress that is associated. McGill warns: "Caution is advised when training this muscle due to the substantial spine compression penalty that is imposed on the spine when the psoas is activated."[12]. Similarly, Sahrmann cautions: "Clinical implications…are to minimize iliopsoas activity in the exercise program when compression and anterior shear are the sources of the patient's pain."[25]. And Oatis believes that low back pain that occurs with hip flexion is probably due to psoas major contracting and causing compression of the lumbar spine[20]. The negative effect of psoas major compression upon the spine can also be inferred from the fact that disc herniation and low back pain have been shown to cause "…significant reduction in the psoas major activity bilaterally…"[26]. This is likely the body's attempt to reduce the physical compression stress of psoas major contraction that is contributing to the pain and dysfunction.

However, there is not universal agreement that the effects of the psoas major stabilization are necessarily deleterious. Gibbons states: "A mechanism to simultaneously flex the hip and stabilize the lumbopelvic region is needed. It does not seem logical that a muscle such as PM (psoas major) would have a detrimental effect to the lumbopelvic region."[2]. It is likely that the cost/benefit ratio of psoas major compression

stabilization would vary from individual to individual and in the end would be a clinical decision based on your client's specific presentation. For those clients with pathologic disc, advanced degenerative joint disease, or other spinal conditions, caution should be exercised when recommending any activities that would greatly increase psoas major engagement.

**Psoas Major and the Sacroiliac Joint**  It is customary to consider the psoas major as a muscle of the hip joint and spinal joints because it attaches across these joints. However, it is often overlooked that the psoas major also crosses the sacroiliac joint. Indeed, only a few sources discuss this[2, 17, 27]. Gibbons states that the "… PM (psoas major) crosses the pelvis and therefore must exert a force on the SIJ (sacroiliac joint)"[2]. Myers describes the roles of the psoas major and piriformis across the sacroiliac joint (see Figure 13) as integral to maintaining a balancing "stabilization…leaving other muscles free and ready to move us in any direction."[17].

Interestingly, the psoas major can also potentially affect the sacroiliac joints in another way. When it contracts, the psoas major creates a pulling force toward both the proximal spinal attachments and the distal femoral attachment. If both attachments are stabilized, and therefore do not move, the psoas major would create a "bowstringing" force upon the pelvis that "pushes" it in the posterior direction as seen in Figure 17[17]. This force would certainly have an effect upon pelvis posture generally as well as specifically upon the sacroiliac joints.

**Psoas Major and Fascial Pulls**  Before leaving our discussion of the psoas major, its fascial associations should be at least be briefly touched upon. After all, the contraction pull of a muscle will always be exerted into all adjacent tissues, both soft and hard, with which it shares fascial attachments. In addition to the fascial attachments into the spine and femur, the psoas major has been shown to have facial attachments into the iliac fascia[22] as well as directly into the sacroiliac joint and pelvic brim[2, 26]. It also interlaces fascially into the diaphragm[23, 26], with potential effects upon breathing, as well as fascial attachments into the fascia and musculature of the pelvic floor[2, 26], with possible ramifications upon pelvic floor dysfunction. Indeed, given that the abdominal cavity is bounded by the diaphragm above and the pelvic floor below, Sandy Sajko postulates that its fascial attachments into the diaphragm and pelvic floor allow for the psoas major to have another avenue in which it can stiffen and stabilize the low back[26].

Regarding longer myofascial tensile (pulling) forces exerted throughout the body, the psoas major is part of



**FIGURE 15**
Lateral view of the psoas major as a person performs a curl-up exercise.
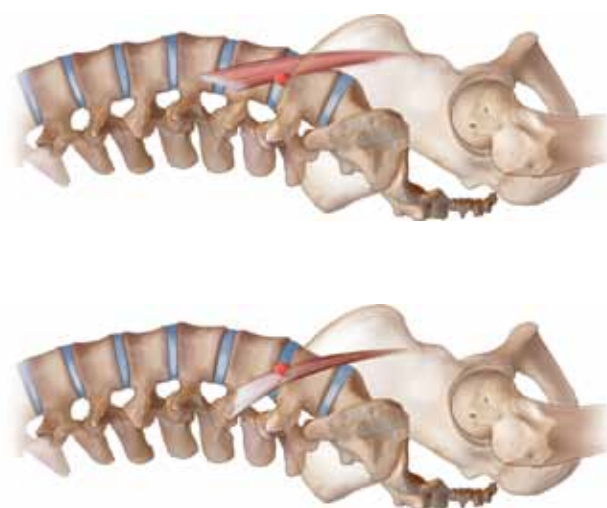


**FIGURE 16**
Lateral view of the psoas major **A**, Anterior fibers. **B**, Posterior fibers.

**FIGURE 17**

If spinal and femoral attachments of the psoas major are stabilized, its contraction would cause a "bowstringing" force that "pushes" posteriorly against the pelvis. Reproduced with kind permission from Joseph E. Muscolino.



**FIGURE 18**

The psoas major is part of the deep front line myofascial meridian. Reproduced with kind permission of Tom Myers, Anatomy Trains: Myofascial Meridians for Manual and Movement Therapists, 2nd Edition. Churchill Livingstone of Elsevier.

the deep front line myofascial meridian, which travels from the tibialis posterior to the suprahyoid musculature (Figure 18)[16]. Therefore, tension created in the psoas major could be transmitted as far distally as the foot, and as far superiorly as the mandible.

## SUMMARY OF PSOAS MAJOR FUNCTION

Evan Osar has stated: "Perhaps no muscles are more misunderstood and have more dysfunction attributed to them than the psoas muscles."[21]. Looking at the multiple joints that the psoas major crosses, as well as its possible subdivision into parts and its multiple fiber directions, it is easy to see why. However, given the intimate and direct association of the psoas major with the spine, as well as its indirect effect upon the spine via pelvic posture, and its role in femoral hip joint function, this muscle merits the needed study for its roles in motion and stabilization. Ironically, it is the intimate location of the psoas major so deeply situated in the abdominal cavity against the spine that makes its investigation that much more challenging. Lying deep within the abdominal cavity makes it more difficult to access via manual palpation, as well as fine wire electromyography.

For this reason, looking at the psoas major from a biomechanical perspective might be the key to understanding this elusive and controversial muscle. What seems clear is that the psoas major crosses and functions across the hip, sacroiliac, and lumbar spinal joints. Given its short moment arm leverage, it would appear that the psoas major functions primarily as a stabilizer at these joints. However, because of its large mass as measured by physiological cross section, it also seems likely that the psoas major can assist in motion, especially flexion at the hip joint. Unifying these principles together, it might be best summarized that the psoas major's principal function is specifically to stabilize the lumbar spine while hip joint flexion motion is occurring.

## FURTHER RESEARCH

There is great need for further research on the psoas major muscle. It would be valuable to continue studying the engagement of the separate parts of the psoas major (upper versus lower and posterior versus anterior) during motion as well as stabilization of the thigh at the hip joint and during motion and stabilization of the lumbar spine. Perhaps most interesting would be to further the study of the role of psoas major engagement in linking spinal stabilization with thigh motion. This research would be enhanced if this engagement could be studied not only when the body is in anatomic position, but also at multiple joint angles of the hip and spine. If

this research is done by EMG study, then placement of fine wire electrodes must be carefully done. However, another approach to psoas major study that might prove especially beneficial would be to do radiographic scans of the psoas major in many individuals, while in anatomic position as well as in other positions of the spine and hip joint to determine the anatomic relationship of the psoas major to the hip and spinal joints. This information can then be used to perform "abstract" biomechanical studies that examine the effects of its lines of pull around the multiple joint axes that it crosses to determine its motion and stabilization forces and therefore its effects upon the body. ■

*Joseph E. Muscolino, DC, is a chiropractor in private practice in Stamford, CT who employs extensive soft tissue manipulation in his practice. He has been a massage educator for more than 25 years and currently teaches anatomy and physiology at Purchase College, SUNY. He is the author of multiple textbooks including* The Muscle and Bone Palpation Manual, The Muscular System Manual *and* Kinesiology *(Elsevier) and* Advanced Treatment Techniques for the Manual Therapist: Neck *(LWW). Joseph teaches Continuing Education Clinical Orthopedic Manual Therapy (COMT) certification workshops around the country and overseas. Visit Joseph's website at* **www.learnmuscles. com** *or his professional facebook page: The Art and Science of Kinesiology.*

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