Body Mechanics

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"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.

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*.

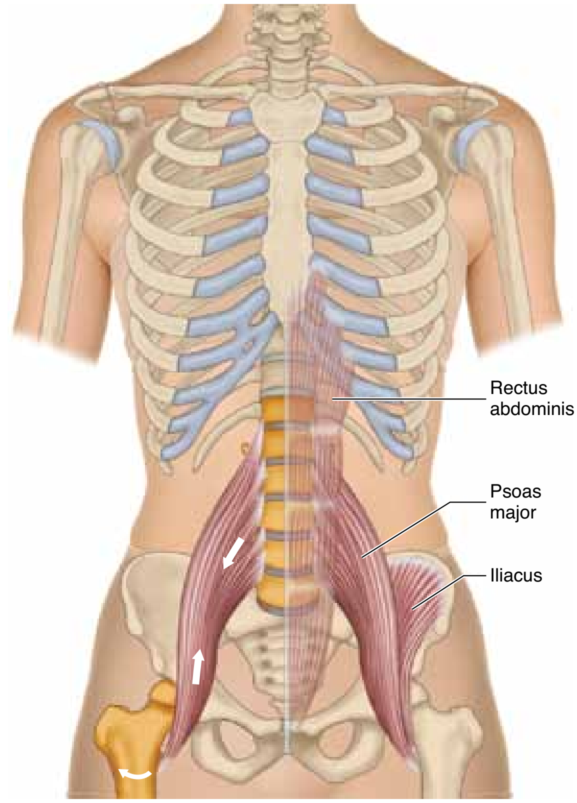

FIGURE 1
Anterior view of the psoas major muscles. The left iliacus has been drawn in; and the left rectus abdominis has been ghosted and drawn in. Reproduced with kind permission from Muscolino, J. E., The Muscular System Manual: The Skeletal Muscles of the Human Body (3rd ed.). Mosby of Elsevier.

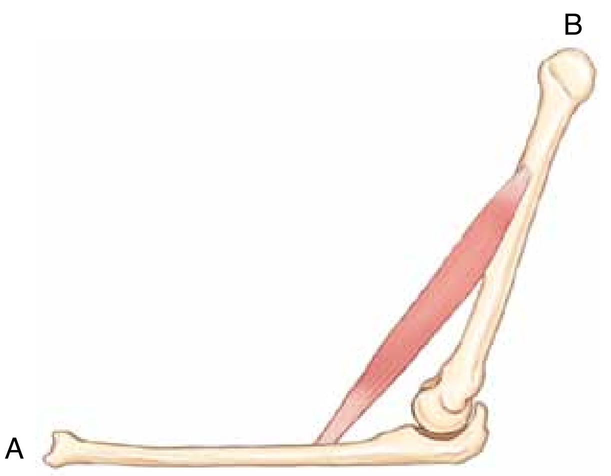

FIGURE 2
A typical muscle attaches to the bones of two adjacent body parts, thereby crossing the joint located between them. Reproduced with kind permission from Muscolino, J. E., The Muscular System Manual: The Skeletal Muscles of the Human Body (3rd ed.). Mosby of Elsevier.

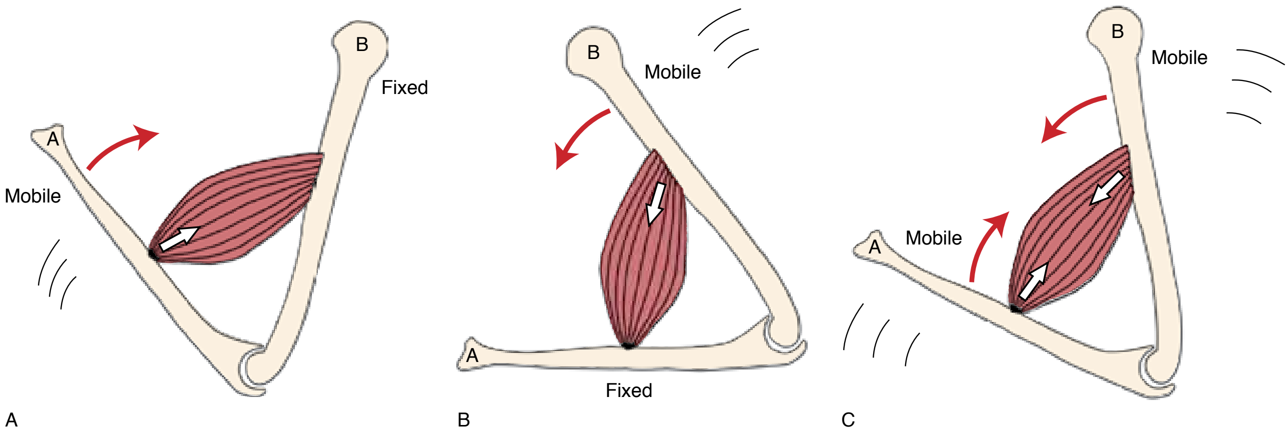

FIGURE 3

Concentric contractions of a muscle. **A**, Attachment "A" moves. **B**, Attachment "B" moves. **C**, Both attachments "A" and "B" move. 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 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

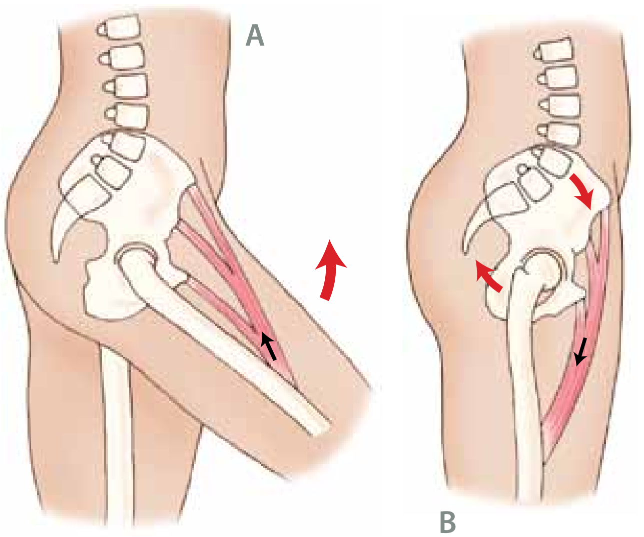

FIGURE 5

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.)

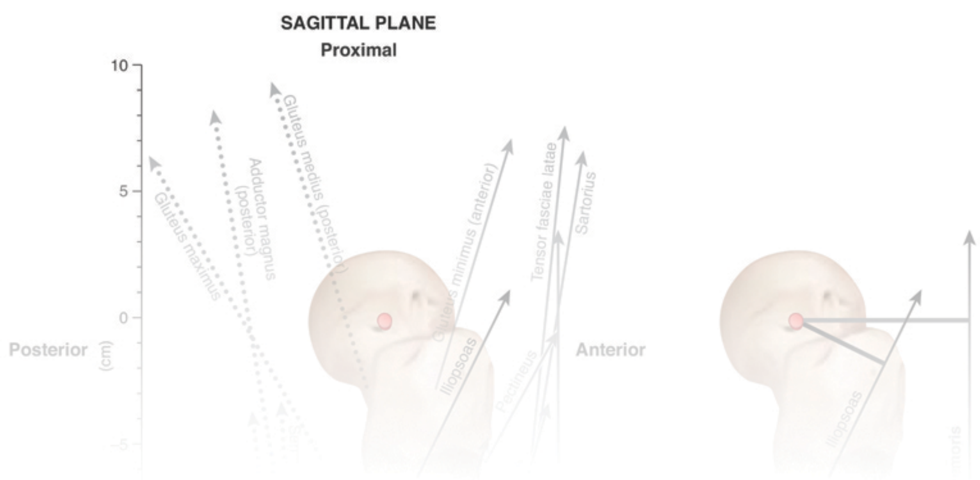

FIGURE 6
Right lateral view demonstrating lines of pull for flexors and extensors at the hip joint. A, Flexors shown with solid lines; extensors shown with dotted lines. B, Moment arms drawn in for the iliopsoas (psoas major) and the rectus femoris. Reproduced with kind permission from Joseph E. Muscolino. Modeled from