Functional Anatomy of the Pelvis and the Sacroiliac Joint

A Practical Guide

Exam Edition

John Gibbons

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Preface

I first realized that there were many areas of the body that still needed more attention when I was trying to consolidate the text for the last chapter of my first book, on muscle energy techniques (METs), which focused specifically on potential muscle weaknesses mainly caused by shortened and tight antagonistic muscles. In particular, I wrote about the effects (possible weakness/inhibition) of the shortened antagonistic muscles of the hip flexors on the gluteal musculature. This last chapter of the MET book inspired me so much to pursue this avenue that I decided to write an entire text on the glutes. Then, while I was writing the book on the glutes, I found that the region of the pelvic girdle and sacroiliac joint (SIJ) kept on cropping up in one way or another in most of the chapters, and so I thought it would be a marvelous idea (at the time of course!) to devote a whole book to the pelvis and SIJ.

So, after many months of contemplation and internal debate, I started writing this book in July 2014, as the initial thought of writing my fourth book had taken me a while to get my head around. Because my book on the glutes had demanded such a vast amount of my time and effort, I wasn't sure if I actually wanted to carry on writing. However, that particular week in July when *Vital Glutes* went to the printers was a huge stepping stone for me. I could finally focus all my attention on writing a new book, this time on what I felt was one of the most neglected areas of the body—the pelvic girdle and in particular the SIJ.

Having taught courses on the specific areas of the pelvic girdle and lower back for many years, I have always wanted to write a book on the SIJ. The course notes each year seem to get thicker and thicker, because of the increasing amount of material. I thought to myself: now is the perfect time in my life to continue writing, and it would also make perfect sense to put pen to paper and write an entire book about this specialized and fascinating area of the body. I would love to think that, in time, this particular book will be used as a core textbook by physical therapy students and potentially serve as their main reference guide.

Another reason for writing this book was because of what I remember a good friend of mine once saying to me, while he was at university studying for a physiotherapy degree. He told me that on one occasion during the first semester, as he was being taught all the different aspects of the specific area relating to the hip joint, the tutor of the course announced that in the following semester the focus would be on the lumbar spine. My friend casually said to the tutor: "What about the bit in the *middle*?" (He was referring to the pelvis and the SIJ.) The tutor replied: "That bit in the middle doesn't move, so don't worry about it"!

I am pleased to say that things have moved on over the last few years, and we now know that the fascinating joints that make up the pelvic girdle do actually have some movement.

People who have come to know me over the last few years, either through attending my courses or as patients or athletes attending the clinic, will know that I am a qualified osteopath. I can honestly say with hand on heart that these individuals naturally presume that all osteopaths spend many years studying the pelvic girdle and SIJ as well as the lumbar spine, and so on. Many patients who present to the osteopathic and chiropractic clinic typically have lower back, neck, or pelvic pain. I have taught a multitude of osteopaths and chiropractors over the years, and all of them seem to have encountered different training methodologies, especially when it comes to their core knowledge base and understanding of the pelvic girdle, and this appears to reflect the specific institute of training they attended.

The reason I refer to osteopaths in particular, and the way they are perceived in terms of their knowledge, is because I want to mention something that shocked and disappointed me. I can recall a time where I was lecturing a four-day intensive course at my venue at the University of Oxford; the course in question was the Advanced Therapy Master-Class. This particular course is designed to deal specifically with the areas of the pelvis and SIJ. As well as many sports therapists and physiotherapists, there were four recently qualified osteopaths attending the course. As the course gradually progressed over the four days they all mentioned to me (individually) that the specific assessment and treatment techniques I was showing them for the area of the pelvis, SIJ, and hip, and even the lumbar spine, were new to them and that they had not been taught those specific assessment and treatment techniques during their own five-year intensive training courses. These four osteopaths were from two different training establishments; I could have understood it if they had been from a single training center, but to have all of them not being taught what I would call basic palpatory, assessment, and treatment techniques not only surprised me but actually disappointed me as well. I am pleased to say that by the end of the course those osteopaths, as well as the other therapists attending the course, had a far better understanding of how to assess and treat athletes and patients presenting with specific lower back and pelvic pain at their own clinics.

Hopefully, this text will answer some (though maybe not all) of the questions you have been asking yourself with regard to your own athletes and patients, or it might even help you gain a better understanding during your own studies of the pelvis and SIJ. You may be reading this text not as a physical therapist, but as someone who actually has pain in the area of the lower back or pelvis, and you may be trying to better understand why that might be and, more importantly, what you can do about it. Whichever of these applies to you, I sincerely hope that you find what you need in this book.

Acknowledgments

The first person I would like to thank is Jon Hutchings of Lotus Publishing. Once again I sincerely thank you for having the confidence in me to continue with the dream of writing, as without you all of my books, including this one, would not have been written and subsequently published. Thanks again, Jon, for having the faith in me to come up with the goods (so to speak). My thanks also to Ian Taylor, who spent a vast amount of time and effort taking and editing the photographs for this book, and to the copy-editor, Steve Brierley, without whose patience and input this book would definitely not read as well as it does!

I would like to include here my recognition of the outstanding work of four particular pioneers in this field of manual therapy—Andry Vleeming, Diane Lee, Philip Greenman, and Wolf Schamberger. Without the dedication and participation of these individual role models this book would not have been written, and for that I truly thank you all.

I am especially grateful to the musculoskeletal physiotherapist Gordon Bosworth, the person who guided me through my initial osteopathy training. Although I acknowledged him in my previous book, I have to include him here too, because the actual fine-tuning with regard to my assessment and treatment skills in the area of the pelvic girdle and SIJ is all down to Gordon. He made my learning and understanding of this fascinating but complex area a pleasure, and for that I thank him with all my heart. I do consider him to be one of the best physical therapists—if not *the* best—I have ever met. He was (and still is) an inspiration to me in becoming the person I am today—so thanks a million, Gordon, for all that effort. I hope mentoring me was as rewarding for you as it was for me!

For their inspiration and moral support during the creation of this book, I must thank my sister, Amanda Williams, her husband, Philip Williams, and their children, James and Victoria; and my mother, Margaret Gibbons. I also wish to thank my son, Thomas Rhys Gibbons, who was 14 at the time of writing, and to whom I dedicate this book. I've always said that Tom is my life—I hope that he can see the success that I have achieved and will be inspired to do the same (though not necessarily as a writer!). It gives me great pleasure to include this brief tribute to these much-loved people in my new book. My only regret is that my father, John Andrew Gibbons, is not here to see or read my books. I am sure, however, that he is looking down on us all with a smile on his face.

I always seem to acknowledge a person who has been in my life the longest (apart from family) at the end of this section. Maybe that's just the way it is—you mention one of the most important people in your life at the end. That person is my fiancée, Denise Thomas; we have been together seven years at the time of writing of this book and I must say I have had the most amazing time with her. Thanks for being the model in the photographs, and thanks a million for all your support.

John Gibbons

Abbreviations

AAJ	atlantoaxial joint
AHC	anterior horn cell
AIIS	anterior inferior iliac spine
ASIS	anterior superior iliac spine
ASLR	active straight leg raise
COG	center of gravity
CT	computerized tomography
DDD	degenerative disc disease
DLS	deep longitudinal sling
ERS	extension, rotation, side bending
FABER	flexion, abduction, external rotation
FAI	femoroacetabular impingement
FAIR	flexion, adduction, internal rotation
FRS	flexion, rotation, side bending
Gmax	gluteus maximus
Gmed	gluteus medius
Gmin	gluteus minimus
GTO	golgi tendon organ
HVT	high-velocity thrust
ILA	inferior lateral angle
ITB	iliotibial band
LLD	leg length discrepancy
L-on-L	left-on-left
L-on-R	left-on-right
MET	muscle energy technique
MR	magnetic resonance
MRI	magnetic resonance imaging
MTA	middle transverse axis
NR	neutral, rotation
OAJ	occipitoatlantal joint
PGP	pelvic girdle pain
PHC	posterior horn cell
PIIS	posterior inferior iliac spine
PIR	post-isometric relaxation
PLS	posterior longitudinal sling
PSIS	posterior superior iliac spine
QL	quadratus lumborum
RI	reciprocal inhibition
ROM	range of motion
R-on-L	right-on-left
R-on-R	right-on-right
SCM	sternocleidomastoid
SIJ	sacroiliac joint
SPD	symphysis pubis dysfunction
SPJ	symphysis pubis joint
STJ	subtalar joint
TFL	tensor fasciae latae
TMJ	temporomandibular joint
TP	transverse process
TVA	transversus abdominis

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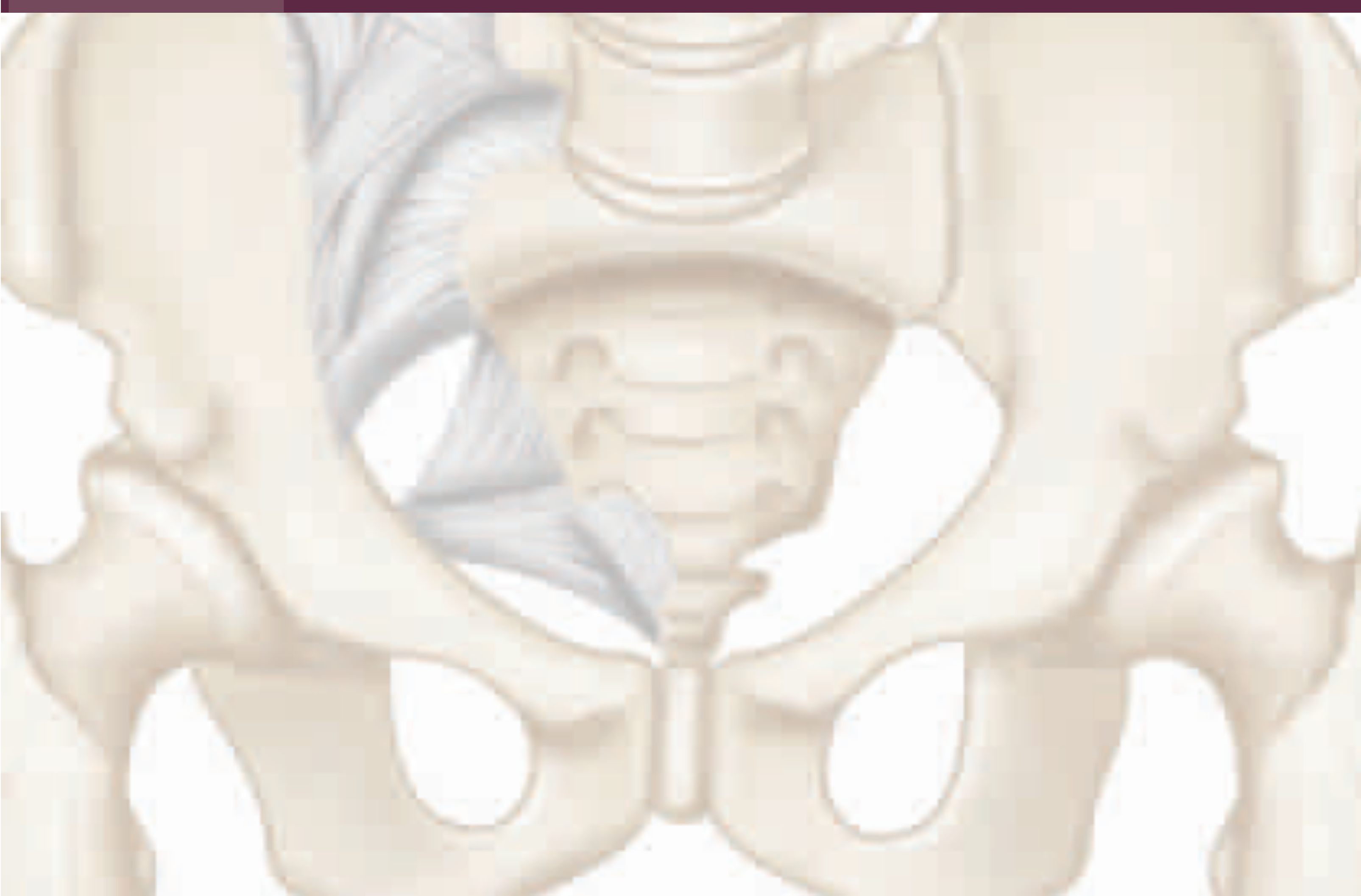
Anatomy of the Pelvis and the Sacroiliac Joint



The pelvic girdle is composed of the sacrum, the coccyx, and the three so-called "hipbones"—the ilium, ischium, and pubis. The bones of the adult pelvis join together to form four joints: the left and right sacroiliac joints (SIJs), the sacrococcygeal joint, and the symphysis pubis joint (SPJ), as shown in Figure 1.1.

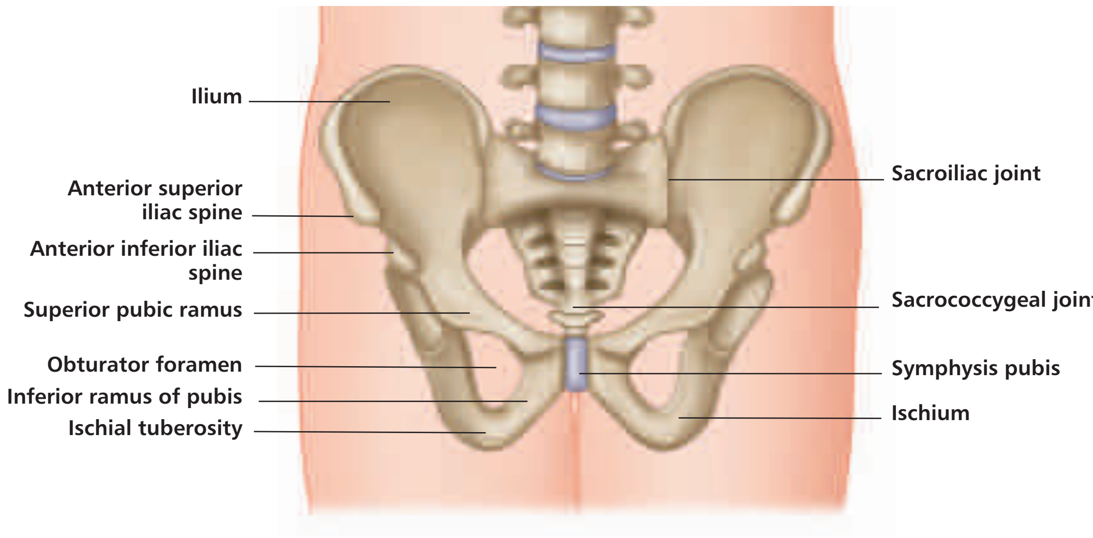


Figure 1.1. Bones of the pelvic girdle, forming the four joints.

At birth the ilium, ischium, and pubis bones are separated by hyaline cartilage; by the end of puberty these bones will have naturally conjoined (fused together), with complete ossification normally occurring by the time a person has reached the age of approximately 20–25. The three bones, once fusion has taken place, are collectively called the *innominate bone*, or simply the *innominate*. On the lateral side of the innominate bone is the acetabulum; this area forms the articulation with the head of the femur to create the iliofemoral (hip) joint, as shown in Figure 1.2.

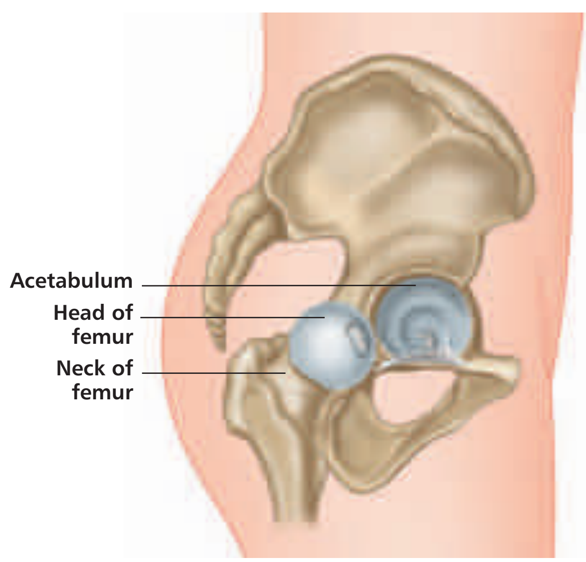


Figure 1.2. Iliofemoral (hip) joint.

Innominate Bones

Ilium

The ilium is fan shaped and is the most superior as well as the largest of the three hipbones; it makes up approximately two-fifths of the deep, cuplike socket of the hip joint, called the *acetabulum*. The body of the ilium together with the sacrum forms the SIJ. This L-shaped articulation is located on the posterior superior aspect of the ilium and has a vertically (vertical plane) orientated "short arm" and a more horizontally (anterioposterior plane) positioned "long arm," as shown in Figure 1.3.

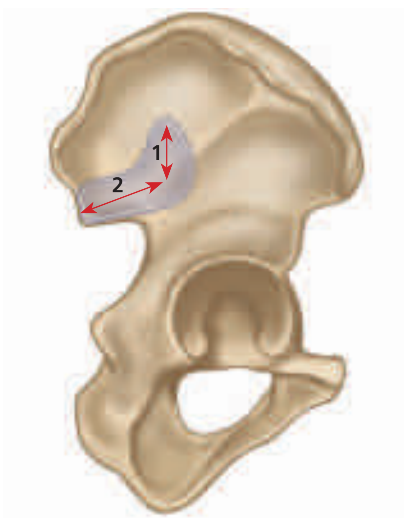


Figure 1.3. L shape of the short (vertical [1]) and long (horizontal [2]) arms of the ilium.

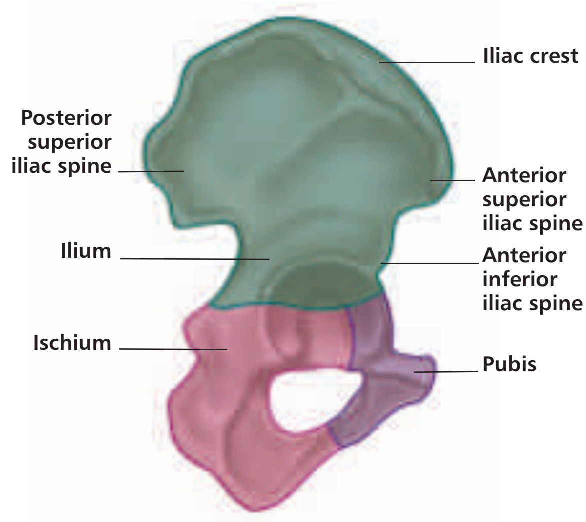


Figure 1.4. Anatomical landmarks of the iliac crest: ASIS, AIIS, and PSIS.

If you place one hand on your hip, you can feel the curved ridge of the superior aspect of the ilium: this is known as the *iliac crest*. From this crest, if you lightly move your fingers down inferior to the anterior aspect of the ilium, you should feel a bony projection known as the *anterior superior iliac spine (ASIS)*; this area allows the attachment of soft tissues (e.g. the sartorius muscle). If you continue slightly inferior to the ASIS, you will come to another bony landmark called the *anterior inferior iliac spine (AIIS)*; this is where one part of the rectus femoris muscle attaches. Palpating the posterior aspect of the ilium as it curves inferiorly, you will feel the bony prominence of the *posterior superior iliac spine (PSIS)*; again this is an attachment for soft tissues. These two bony projections (ASIS and PSIS) are commonly used as palpatory landmarks, as shown in Figure 1.4, when one is assessing the position of the pelvic girdle.

Ischium

The ischium is narrower than the ilium bone and is located inferior to the ilium and behind the pubis. The ischium has an easily palpable landmark called the *ischial tuberosity*, as shown in Figure 1.5; it is commonly called the *sit bone* and provides the necessary landmark for the attachment of the hamstrings. It is this part of the ischium (tuberosity), along with the coccyx, on which you rest your body weight while adopting a sitting position. The ischium is the strongest of the three bones and forms approximately two-fifths of the acetabulum (hip socket).

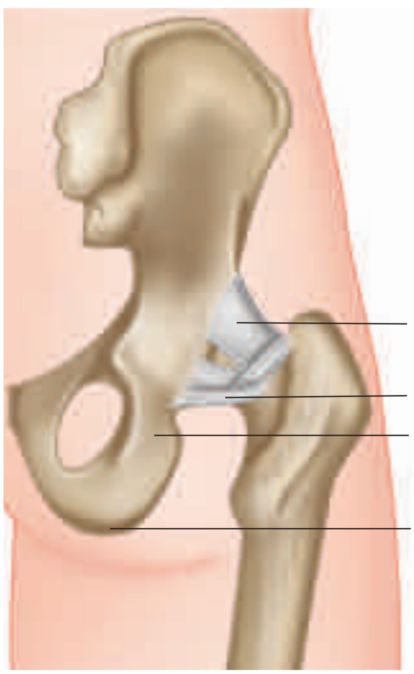


Figure 1.5. Ischium and ischial tuberosity.

Pubis

The pubis, or pubic bone, is the most anterior as well as the smallest of all the three hipbones and makes up approximately one-fifth of the acetabulum. The body of the pubis is wide, strong, and flat, and together with the opposite pubic bone makes up the SPJ. This joint is classified as an *amphiarthrosis*, as it is connected centrally by a broad piece of fibrocartilage, as shown in Figure 1.6. On the superior aspect of the pubis there is a bony projection called the *pubic tubercle*; this structure allows the attachment of the inguinal ligament and is also used as a palpatory landmark when one is assessing the position of the pelvic girdle.

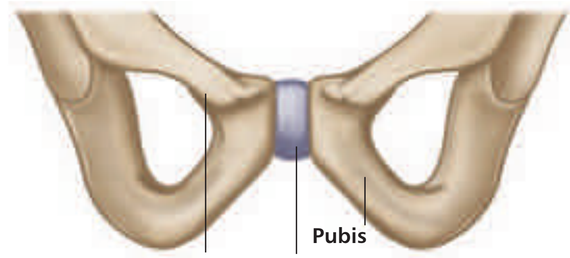


Figure 1.6. Pubis, pubic tubercle and SPJ.

Sacrum

The sacrum (sacred bone) is a large triangular bone located at the base of the lumbar spine and forms the back part of the pelvic cavity. The sacrum starts out from birth as five individual bones before starting to fuse between the ages of 16 and 18; the sacrum is considered to have fully fused into a single bone by the time you have reached 34 years of age.

Considerable differences in the shape of the sacrum between individuals, as well as structural differences between the left and right sides, are well documented. The connection of the sacrum to the ilium forms the SIJ.

The superior aspect of the sacrum is called the *sacral base* and is primarily made up of the 1st sacral segment; the base is angled in a forward direction to form a concavity. The opposite end of the sacrum is called the *sacral apex* and this is made up of the 5th sacral segment, as shown in Figure 1.7. The natural position of the sacrum is called the *sacral angle* and is generally thought to be in the range 40–44 degrees (Figure 1.8), although, as discussed by some authors, the angle can be anywhere from 30 to 50 degrees. Moreover, a specific type of motion called *nutation* (a nodding motion, which will be discussed later) can be responsible for an increase in this angle by anywhere between 6 and 8 degrees on standing up (from a sitting position). The sacral angle increases because of the change in the curvature of the lumbar spine, from an initial flexion curvature when sitting, to an extension curvature (lumbar lordosis) when standing, as one performs the motion from a sitting to a standing posture. This sacral movement allows the whole of the spinal column to adopt an upright position.

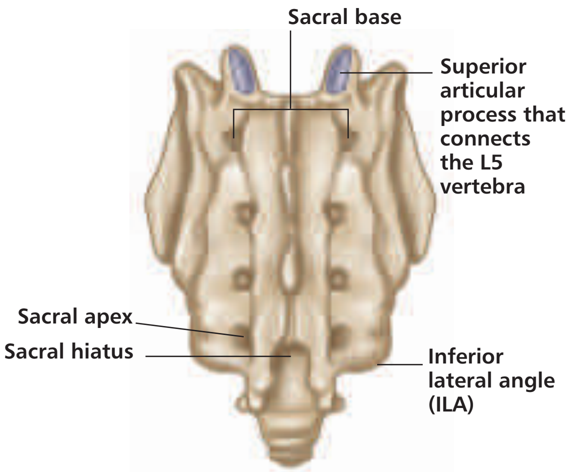


Figure 1.7. Anatomical landmarks of the sacrum (posterior view).

On the lateral sides of the sacrum located between the levels of the first three sacral vertebra (S1–S3) are the *alae* (wings): these auricular (earlike) L-shaped areas of the sacrum make up the articulation with the ilium—i.e. the SIJ. In an earlier paragraph regarding the ilium I mentioned that there is a short vertical arm and a long anteroposterior (horizontal) arm, as shown in Figure 1.8, which will naturally dovetail with each other, like pieces of a jigsaw puzzle.

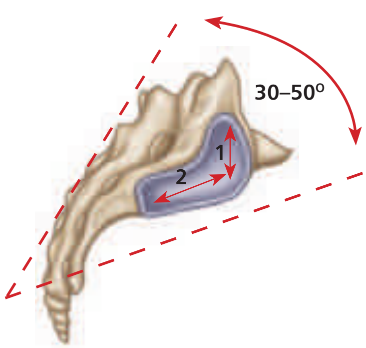


Figure 1.8. The short (vertical [1]) and long (horizontal [2]) arm of the sacrum, and the sacral angle (lateral view).

Another way of looking at the sacrum is as a continuation of the lumbar spine, while the SIJs on either side are mimicking what I generally call *atypical facet joints*. You can think of the sacrum as a single vertebra, and the left and right SIJs as the articulating facet joints, with the superior articular facet being the ilia component and the inferior articular facet being the sacral component (illustrated in Figure 1.11).

Coccyx

The coccyx is the continuation and endpoint of the vertebral column and is commonly referred to as the *tailbone*. It has between three and five (normally four) vertebral segments called the *coccygeal vertebrae*, and most textbooks state that these are actually fused; some authors, however, maintain that the coccygeal vertebrae are indeed separate and individual entities (Figure 1.9).

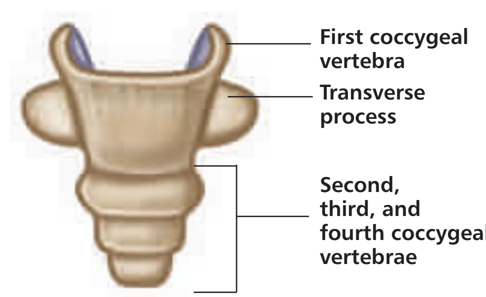


Figure 1.9. Coccyx bone and the individual segments.

There are many muscles with attachments directly on the coccyx: for example, the pelvic floor muscles attach to the anterior surface of the coccyx, and the gluteus maximus (Gmax) muscle and ligaments attach to the posterior surface. Likewise, some ligaments attach directly to the coccyx, such as the sacrococcygeal ligament and some of the fibers of the sacrospinous and sacrotuberous ligaments. The coccyx also plays a role in weight bearing (while sitting), as it forms part of the *tripod* structure, working in conjunction with the left and right ischial tuberosities (sit bones).

Symphysis Pubis Joint

The symphysis pubis joint (SPJ) is classified as a *non-synovial fibrocartilaginous amphiarthrosis*, connecting the left and right pubic bones.

In adults only 0.08" (2mm) of movement (shift) and one degree of rotation are considered to be possible in this joint; however, these values will increase in women during pregnancy and childbirth. The available movement of the SPJ is also influenced by the natural shape of the joint, and by muscular activation from the adductor and abdominal muscles.

The ends of each pubic bone are covered by hyaline cartilage that connects to the piece of fibrocartilage located in the center of the SPJ. The joint has strong superior and inferior ligaments and a thinner posterior ligament (Figure 1.10).

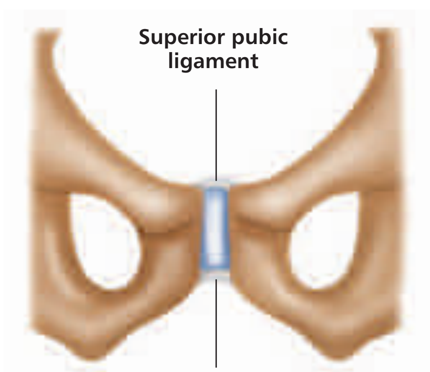


Figure 1.10. Symphysis pubis joint and associated ligaments.

One can think of the design of the symphysis pubis as being similar to the intervertebral discs of the spine, with a central disc of fibrocartilage that cushions against compressive loads, as well as providing shock absorption and contributing to passive stabilization. Because of this similarity, the articular disc of the SPJ is also vulnerable to both degeneration and trauma, particularly when the joint is subjected to traumatic or repetitive shear forces (e.g. osteitis pubis).

Functionally, the SPJ helps to resist tension, shearing, and compression forces, and remarkably is able to widen during pregnancy. The anatomist Andreas Vesalius, who challenged the Hippocratic belief that the pubic bones separated during childbirth, was the first to recognize this joint in 1543.

Sacroiliac Joint

Lower back pain and the link with the sacroiliac joint (SIJ, or SI joint) date back to the era of Hippocrates (c.460–377 BC); the medical practitioners (obstetricians) at the time felt that under normal conditions the SIJs were immobile. I am very pleased to say that things have progressed enormously over the last few decades with all the information now readily available in respect of the general consensus of the role and function of the pelvic girdle, and in particular of the SIJ. I can guarantee, though, that over time some things will nevertheless change, so this book may well need to be updated in the future.

I have been lecturing courses on the pelvic girdle, and on the SIJ in particular, for many years at my venue based at the University of Oxford, which means I have come into contact with thousands of physical therapists, ranging from osteopaths and physiotherapists to chiropractors and lots of sports therapists, to mention but a few. If I am honest with myself, I personally consider that the area of the pelvis is a relatively difficult subject to try to get across to my students (mainly therapists); this is because I consider the SIJ to be something of a "mystery" to many therapists, and it becomes especially difficult when I am trying to explain the subject matter to my athletes and patients.

The majority of physical therapists attending the course on the pelvic girdle tell me at some point that they see patients and athletes on a daily basis with what they consider to be a presentation of *sacroiliac joint dysfunction*. In the past, patients with presenting SIJ issues have even been referred directly to them by the local GP or a colleague.

Vleeming et al. (2007) say that mobility of the pelvic joints is difficult to measure objectively, especially in the weight bearing position, and that feeling motion at the sacroiliac joint during active and passive motion is difficult to prove.

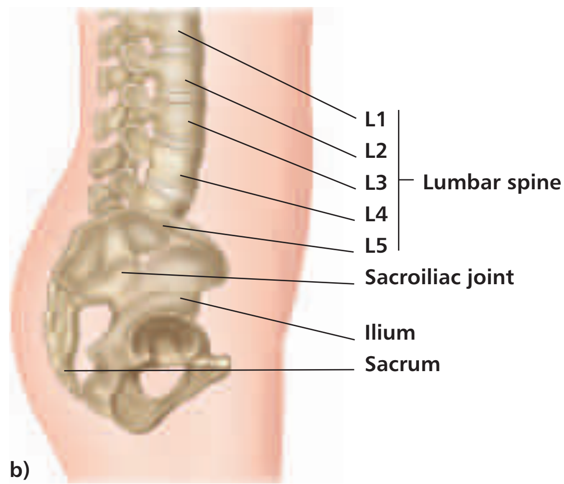
Bearing in mind the above quote, you can imagine that teaching a specific course on this fascinating but undoubtedly complex area of the body is not as straightforward as one might think.

Anatomy

The SIJ, as shown in Figure 1.11, is located between the sacrum and the ilium and is classified as a *true synovial arthrodial joint*, as it contains a joint capsule, synovial fluid, articular cartilage, and a synovial membrane.

The SIJ is unique: on the ilia side, the cartilage is made up mainly of fibrocartilage, whereas on the sacral side, the cartilage consists of hyaline, or articular, cartilage. The articular (hyaline) cartilage is thicker (0.04–0.12", or 1–3mm) on the sacral side than on the ilia side. Kampen and Tillman (1998) found that in adults the cartilage on the sacral surface of the joint can reach 0.16" (4mm) in thickness, but does not exceed 0.04–0.08" (1–2mm) on the iliac surface. The lack of thickness of the cartilage on the ilia side might be one of the factors responsible for hardening (sclerosis).

Regarding the shape of the SIJ, different characteristics between individuals have been clinically proven; moreover, there can be significant structural differences between the left and right sides of the joint surfaces within the SIJs of the same individual. There is also clear evidence of the fact that the paired SIJs, and even the PSISs, are generally asymmetric in appearance, which can also be the case in patients and athletes who present with no symptoms of pain or dysfunction (i.e. are asymptomatic).



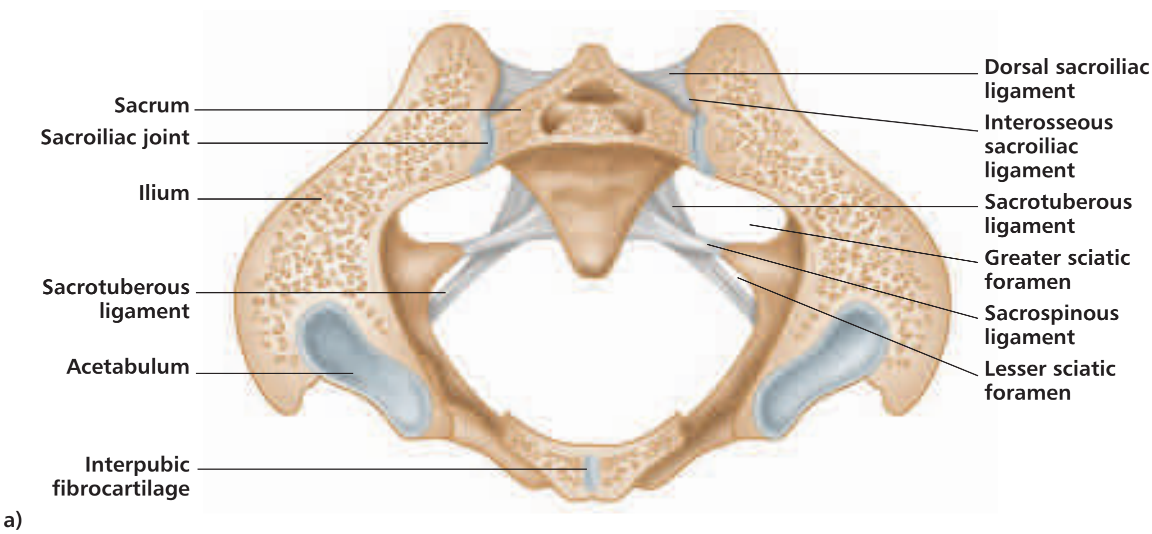


Figure 1.11. Anatomy of the SIJ; a) transverse section; b) lateral view.

The SIJs have an auricular L-shaped appearance, similar to a kidney, with a short (vertical) upper arm and a longer (horizontal) lower arm (as already mentioned earlier).

In terms of motion, the pelvis is capable of moving in all three planes of the body: flexion and extension in the sagittal plane (forward and backward bending); lateral flexion (side bending) in the frontal plane; and rotation of the trunk in the transverse plane. It has been debated that the SIJ can move anywhere between 2 and

18 degrees, but more recent evidence provided by many clinicians demonstrates that there are roughly 2–4 degrees of rotation and 0.04–0.08" (1–2mm) of translation. Studies have shown us that movement is possible, but only in very small amounts; this was demonstrated by Egund et al. (1978) and Sturesson et al. (1989, 2000a, 2000b), who found the motion of the SIJ to be at best approximately 2–4 degrees in rotation and 0.08" (2mm) in translation.

We know that when we are developing through the natural aging process, the SIJ characteristics change. In early life the SIJ surfaces are in general initially flat, but as we start to walk and progress through puberty, these surfaces develop distinct ridges and grooves and lose their naturally flattened appearance. These ridges and grooves actually fit into one another to some extent; this will potentially aid the overall stability of the SIJ, while still allowing some degree of movement.

The text *Greenman's Principles of Manual Medicine* (DeStefano 2011) mentions that "during the aging process, there is an increase in the grooves on the opposing surfaces of the sacrum and ilium that appears to reduce available motion and enhance stability." The author also says that "it is of interest to note that the age at which the incidence of disabling back pain is highest (range: 25 to 45 years) is the same age when the greatest amount of motion is available in the sacroiliac joints."

Because of the relationship of the three main pelvic joints (the two sacroiliac and the symphysis pubis), as well as their relationship to the iliofemoral joint (hip joint), a dysfunction existing in any one of these joints can have a direct impact on the other two/three joints.

Ligaments of the SIJ

The SIJ has very strong ligaments, which increase the joint's stability and make potential dislocations very rare.

Stability of the SIJ is provided partly through ligamentous attachments. These specific ligaments will provide joint integrity as well as resistance to shearing-type forces. The ligaments that bind the sacrum directly to the innominate are (Figure 1.12):

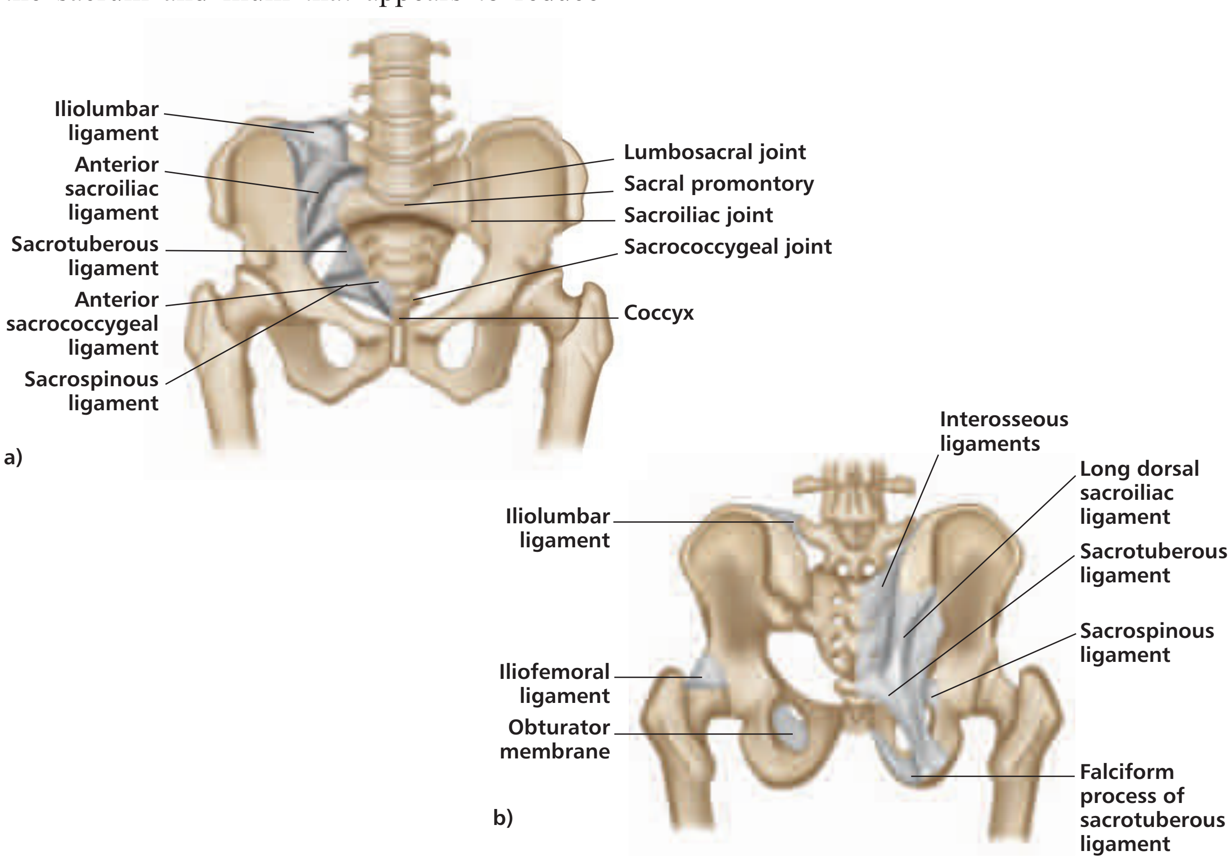


Figure 1.12. Ligaments relating to stability of the SIJ; a) anterior view, b) posterior view.

- Sacrotuberous
- Sacrospinous
- Interosseous
- Long dorsal (posterior sacroiliac)

The iliolumbar ligament will also have a stabilizing influence on the SIJ as well as on the lumbar spine.

Sacrotuberous Ligament

The sacrotuberous ligament attaches from the PSIS and also has an attachment to the posterior sacroiliac ligaments. The ligament then continues and attaches onto the ischial tuberosity and splits into three individual bands: the outer (lateral) side attaches from the PSIS to the ischial tuberosity; the inner (medial) band attaches from the coccyx to the ischial tuberosity; and the superior band connects the PSIS to the coccyx.

Four muscles have an attachment directly to the sacrotuberous ligament and will contribute to the overall stability of the SIJ:

- Biceps femoris
- Gluteus maximus (Gmax)
- Multifidus
- Piriformis

Vleeming et al. (1989a) found that in approximately 50% of subjects the lower border of the sacrotuberous ligament was directly continuous with the tendon of the origin of the long head of biceps femoris; this muscle could therefore act to stabilize the SIJ via the sacrotuberous ligament.

Part of the role of the sacrotuberous ligament is to resist the anterior nodding type of motion of the sacrum known as *nutation*. This ligament will also prevent posterior rotation of the innominate bone with respect to the sacrum. If for some reason there is laxity in the sacrotuberous ligament (along with the sacrospinous ligament), the decreased tension can result in a posterior rotation of the innominate bone, and also lead to increased nutation of the sacrum.

Sacrospinous Ligament

The sacrospinous ligament has an attachment from the lateral aspect of the sacrum and coccyx and attaches to the spine of the ischium, appropriately named the *ischial spine*. The ligament has the appearance of a thin triangle and, together with the sacrotuberous ligament, it modifies the greater sciatic notch in the greater sciatic foramen. In one respect, the function of the sacrospinous ligament is similar to that of the sacrotuberous ligament: it prevents posterior rotation of the innominate bone relative to the sacrum, and also limits nutation (forward motion) of the sacrum relative to the innominate bone.

Interosseous Ligament

The interosseous ligament consists of a dense, short, thick collection of strong collagenous fibers that run in a horizontal plane and connect the sacral tuberosities of the sacrum to the ilium. This ligament lies deep in the narrow recess between the sacrum and the ilium, and has deep and superficial components to it. The main function of the interosseous ligament is to prevent a separation or abduction of the SIJ by strongly binding the sacrum to the ilium, as this will help secure the SIJ interlocking mechanism.

Long Dorsal Ligament (Posterior Sacroiliac Ligament)

The long dorsal ligament attaches from the medial and lateral crests of the sacrum and to the PSIS. There is also a connection of this ligament to the thoracolumbar fascia, as well as to the multifidus and erector spinae muscles.

The long dorsal ligament mainly resists counter-nutation of the sacrum (posterior nutation) as well as anterior rotation of the innominate bone. Consequently, this ligament will naturally slacken when the sacrum is in a state of nutation and/or if there is posterior rotation of the innominate bone.

If sacral torsion is present (discussed in later chapters) and the sacral base is found to be "posterior," this ligament will be under constant tension and may be tender when palpated.

Lee (2004, p. 22) mentions that the skin overlying the long dorsal sacroiliac ligament is a frequent area of pain in patients with lumbosacral and pelvic girdle dysfunction, and that tenderness on palpation of the ligament does not necessarily incriminate this tissue, given the nature of pain referral from both the lumbar spine and the SIJ.

Iliolumbar Ligament

The iliolumbar ligament is a very strong ligamentous structure; it attaches from the transverse processes (TPs) of the 4th and 5th lumbar vertebrae and travels to the inner border of the ilium.

This ligament, which has five individual bands, is one of three vertebrae–pelvis ligaments responsible for stabilizing the lumbosacral spine in the pelvis, along with the two mentioned already, namely the sacrospinous and sacrotuberous. The main function of the iliolumbar ligament is essentially to limit the motion of the lumbosacral junction by stabilizing the connection between the pelvis and the lower lumbar vertebrae (L4 and L5).

Function of the SIJs

The SIJs' primary responsibility is to transfer the weight of the upper body to the lower extremities. The body weight is transferred through the vertebral column to the lumbar spine (L5), to the sacrum and across the SIJs to the ischial tuberosities, and then out to the acetabula of the hip joints. This mechanism of bony attachments demonstrates the SIJs' role as weight-bearing joints, as shown in Figure 1.13. The SIJs are also able to transfer the forces in the opposite direction when one is walking, standing, or sitting: the pressure is directed through the legs to the innominates and the sacrum, and then dissipated upward through the lumbosacral junction.

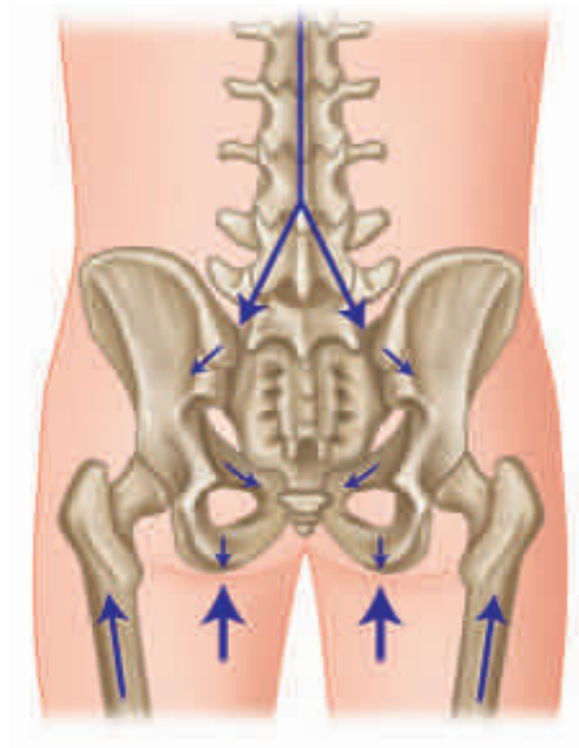


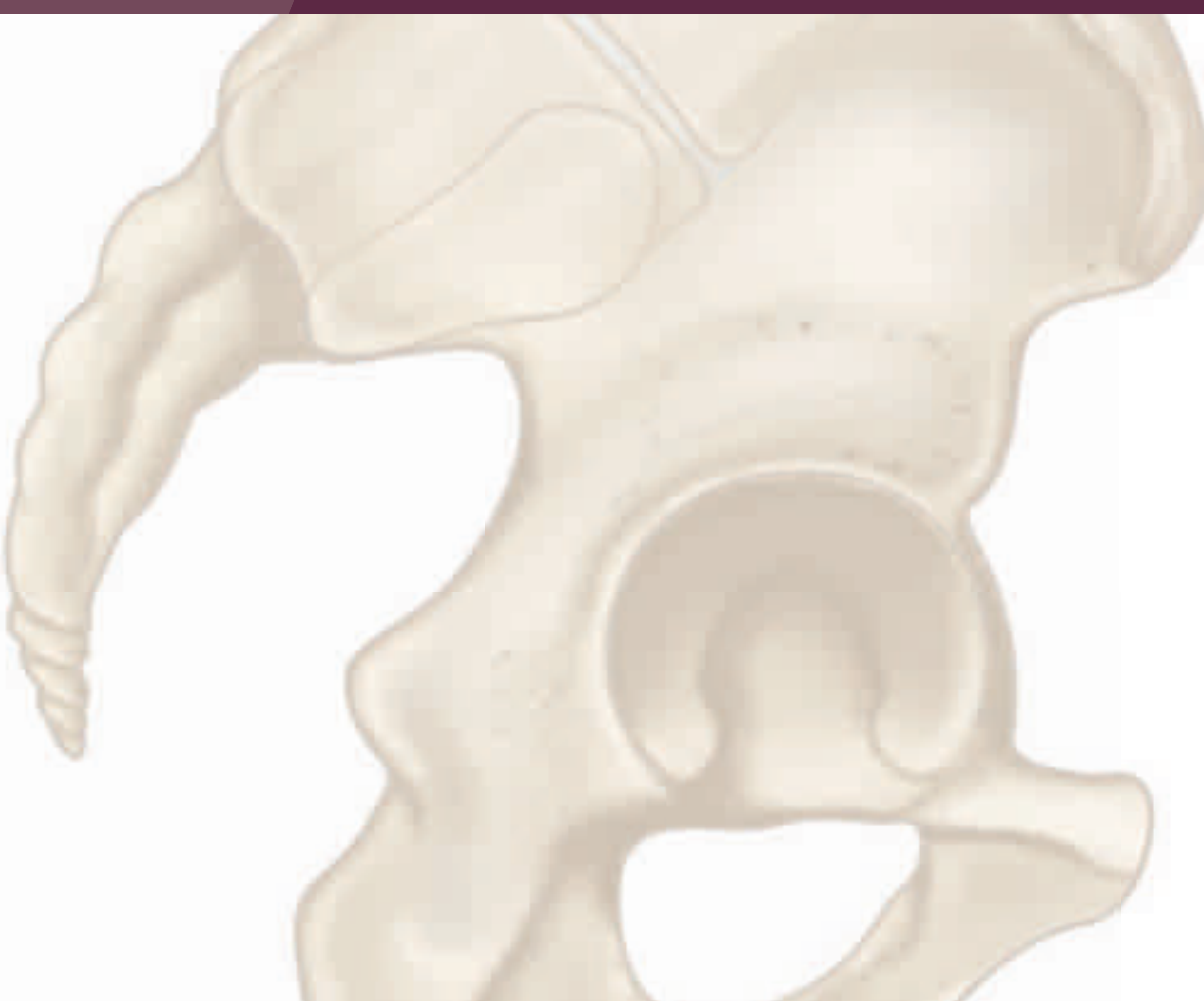
Figure 1.13. Weight transfer forces through the pelvis and the SIJs.

In their secondary role, the SIJs can be thought of as shock absorbers (mainly at the point of heel contact), as they help cushion the increased stress that is forced upon the lumbar spine and in particular upon the lower lumbar intervertebral discs. Authors in the past have suggested that the incidence of lower lumbar disc disease/degeneration increases when the SIJs present with pathological changes.

Lee and Vleeming (2007) discussed the analysis of gait mechanics and demonstrated that the SIJs provide sufficient flexibility for the intra-pelvic forces to be transferred effectively to and from the lumbar spine and lower extremities.

2

Motion of the Pelvis and the Sacroiliac Joint



Previous authors have suggested that there are approximately 14 individual types of dysfunction possible within the pelvic girdle complex. This in itself suggests to me that, because there are so many types of potential dysfunction which can be present within the pelvic girdle, there logically have to be just as many types of natural motion available as well.

Pelvis Motion

Put in a relatively simple way, there are three main types of motion available within the pelvic girdle:

- Sacroiliac motion, which comprises the motion of the sacrum on the innominate bone.
- Iliosacral motion, which comprises the motion of the innominate bone on the sacrum.
- Symphysis pubis motion, which typically relates to the motion of the pubic bone on one side with respect to the bone on the other side.

Sacroiliac Motion

Sacroiliac motion is the movement of the sacrum within the innominate bone, and there are two main types: (1) anterior/forward motion, or nutation (think of this as sacral flexion); and (2) posterior/backward motion, or counter-nutation (think of this as sacral extension). Bilateral movement of the sacrum occurs with forward and backward bending of the trunk; on the other hand, unilateral movement of the sacrum occurs with flexion and extension of the hip joint and lower limbs, such as when we initiate the walking/gait cycle.

Nutation

The word *nutation* actually means “nodding”, and this motion of the sacral base (top part of the sacrum) is directed anteriorly and inferiorly, while the sacral apex (bottom part of the sacrum)/coccyx moves posteriorly and superiorly relative to the innominate bone, as illustrated in Figure 2.1(a).

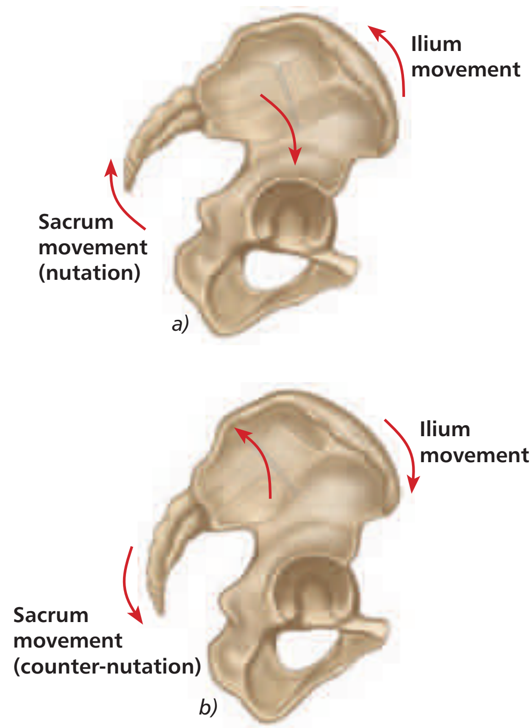


Figure 2.1. (a) Sacral nutation. (b) Sacral counter-nutation.

During nutation (which is also known as *anterior nutation*), the sacrum is considered to glide inferiorly down the short (vertical) arm and posteriorly along the long (horizontal) arm of the L-shaped articular surface (see Figure 2.2).

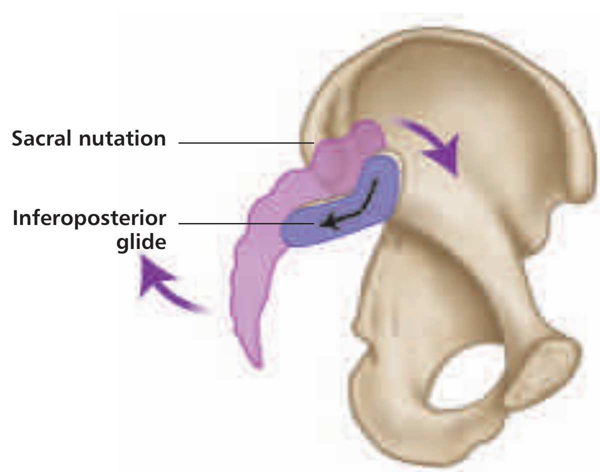


Figure 2.2. Sacral nutation: the sacrum glides inferiorly down the short arm and posteriorly along the long arm.

The natural wedge shape of the sacrum, as well as the ridges and grooves of the articular surfaces, limits nutation. In addition, the interosseous, sacrotuberous, and sacrospinous ligaments will limit how much nutation is possible, as they become taught in this position; this is considered to be the most stable position.

Vrahas et al. (1995) mention that nutation represents a movement that tightens most of the SIJ ligaments, among which are the vast interosseous and dorsal sacroiliac ligaments (with the exception of the long dorsal ligament), thereby preparing the pelvis for increased loading.

Counter-Nutation

In counter-nutation the sacral base moves posteriorly and superiorly, while the sacral apex/coccyx moves anteriorly and inferiorly relative to the innominate bone (Figure 2.1(b)). During this type of motion (which is also known as *posterior nutation*), the sacrum is considered to glide anteriorly along the long arm and superiorly up the short arm of the L-shaped articular surface, as shown in Figure 2.3.

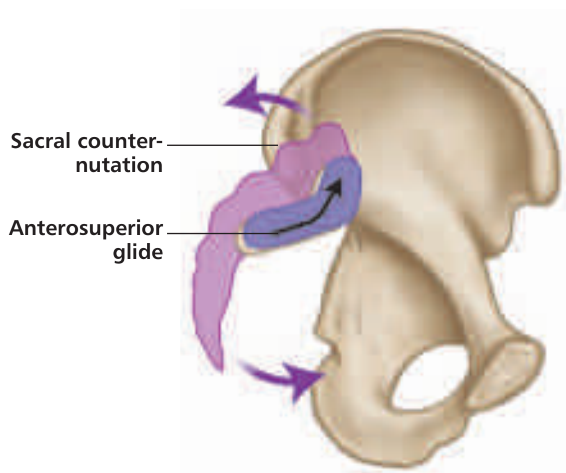


Figure 2.3. Sacral counter-nutation: the sacrum glides anteriorly along the long arm and superiorly up the short arm.

The long dorsal ligament limits this specific motion of counter-nutation. Because of the laxity of the interosseous and sacrotuberous ligaments, this sacral position of counter-nutation is considered to be the least stable.

Iliosacral Motion

Iliosacral motion is the movement permitted by the innominate bone on the sacrum. Bilateral movement (anterior and posterior rotation) of the innominate bones occurs with forward and backward bending of the trunk; on the other hand, unilateral movement (anterior and posterior rotation) of the innominate bone occurs with flexion and extension of the hip joint and lower limbs, for example during the gait cycle (similar to unilateral sacral motion).

Anterior Innominate Motion

When the hip and lower limb are extended, the innominate rotates anteriorly as the L-shaped articular surface glides inferiorly down the short arm and posteriorly along the long arm, as shown in Figure 2.4. This anterior motion of the innominate is reminiscent of counter-nutation of the sacrum.

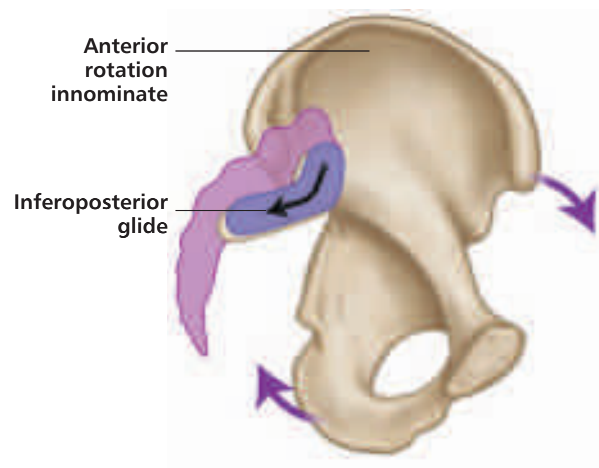


Figure 2.4. Anterior rotation of the innominate bone: the L-shaped articular surface glides inferiorly down the short arm and posteriorly along the long arm.

Posterior Innominate Motion

When the hip and lower limb are flexed, the innominate rotates posteriorly as the L-shaped articular surface glides anteriorly along the long arm and superiorly up the short arm, as shown in Figure 2.5. This posterior motion of the innominate is reminiscent of nutation of the sacrum.

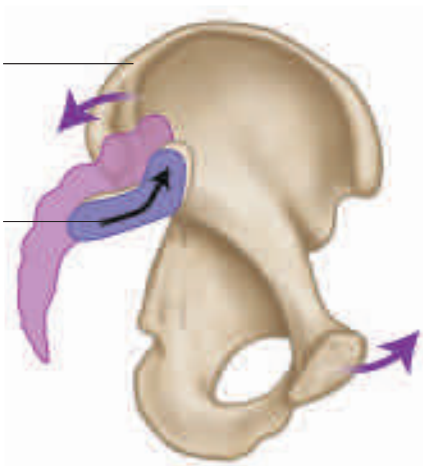


Figure 2.5. Posterior rotation of the innominate bone: the L-shaped articular surface glides anteriorly along the long arm and superiorly up the short arm.

Symphysis Pubis Motion

Anteriorly, the two hipbones are joined together to form a connection known as the *symphysis pubis joint*. During normal walking, the symphysis pubis joint acts as a type of pivot point for the motion of the two hipbones.

Although movement is possible at the symphysis pubis joint, it is normally restricted because of the attachments of the strong superior and inferior ligaments. The limited motion that is available mainly occurs during the walking cycle; however, movement is also possible at this joint when one adopts a stabilized standing position while balancing on one leg.

Symphysis pubis dysfunction (SPD) is generally classified according to the position in which the joint is fixed—either a *superior symphysis pubis* or an *inferior symphysis pubis*, as shown in Figure 2.6.

Studies have shown that if you were to maintain a one-legged standing position for a few minutes, a superior motion (shear) of the symphysis pubis would be seen. If the one-legged motion is maintained over an extended period of time, recurrent SPD can result.

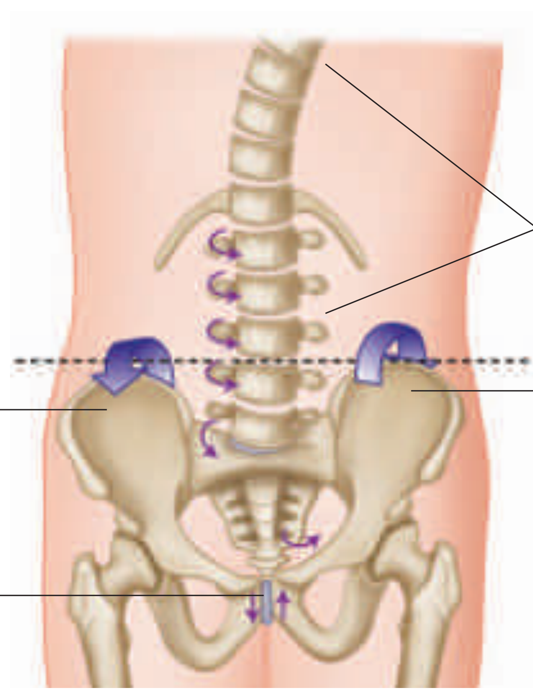


Figure 2.6. Superior and inferior motion of the symphysis pubis joint.

SPD is commonly associated with pregnancy and childbirth; it is thought to affect to varying degrees around one in five women who are pregnant, with around 5–7% of them continuing to experience ongoing painful symptoms after childbirth. During pregnancy, and especially during childbirth, the symphysis pubis ligaments become more lax in order to allow a natural separation of this joint, since this increased movement is needed to widen the internal diameter of the pelvic bowl.

Combined Sacroiliac and Iliosacral Motion

We have looked at the individual motion of the sacrum during nutation and counter-nutation within the innominate bones (sacroiliac) and how the innominate bone rotates around the sacrum (iliosacral). Next, we will combine the motion of the sacroiliac, iliosacral, lumbar, and hip joints during forward and backward bending of the trunk.

When the pelvic girdle, i.e. the two innominate bones and the sacrum, rotate as a unit through the hip joint, this motion is known as an *anterior pelvic tilt* or a *posterior pelvic tilt*.

Bilateral Motion—Forward Bending

Bilateral (both sides) nutation and counter-nutation are the natural movements that the sacrum performs when we forward and backward bend our trunk while in a stable position on two legs.

On the initiation of forward bending of the trunk, the pelvic girdle will shift posteriorly to control the center of gravity in order to maintain the balance. The sacrum will be in a position of nutation and will stay there throughout the full range of motion (ROM). The left and right innominates rotate symmetrically on the femur in an anterior direction (anterior pelvic tilt), and the PSIS will move symmetrically in a cephalic direction (superior) as the lumbar spine (L5) flexes on the sacrum. As trunk flexion continues, there will come a natural point when tension is increased within the sacrotuberous ligament, biceps femoris, and thoracolumbar fascia, and a position where sacral nutation ceases. At this point the innominate bones continue rotating anteriorly; however, because of the increased tension in the soft tissues (explained earlier), especially the hamstrings, the final position of trunk flexion is that in which the sacrum is considered to be in a position of *relative* counter-nutation, even though the sacrum will appear to be in a position of nutation, as shown in Figure 2.7.

Figure 2.7. Bilateral motion during forward bending.

On the return to a standing position, the sacrum remains in a position of nutation until the erect posture is achieved; at this crucial point, the sacrum slightly counter-nutates to maintain a suspension between the two innominate bones. (Note that, even though I have mentioned counter-nutation, the sacrum still maintains an overall position of nutation.)

Bilateral Motion—Backward Bending

This time, on the initiation of backward bending, the pelvic girdle will shift anteriorly, while the innominate bones symmetrically rotate posteriorly on the femur (posterior pelvic tilt); the PSIS can be seen and felt to rotate in a caudal direction (inferiorly), while the thoracolumbar spine continues extension until L5 extends on the sacrum, as shown in Figure 2.8. The sacrum remains in a position of nutation throughout backward bending; this position is considered to be the most stable because of the compression of the SIJs.

Figure 2.8. Bilateral motion during backward bending.

Unilateral (One Side) Motion of the Sacrum

During the walking/gait cycle, the sacrum is required to perform its natural motion in a way that is completely opposite to that during forward and backward bending movements. This time we need a specific type of unilateral (one-sided) motion of the sacrum, not a bilateral motion. What I mean by this is the following: as we walk from point A to point B, we need one side of the sacrum (e.g. the left side) to move forward into *nutation*, while at the same time the opposite side (right side in this case) is moving backward into *counter-nutation* (or posterior nutation). This movement gets a little bit more complex, as the nutation/counter-nutation will naturally induce a movement of *sacral rotation*. The problem we encounter now is that when you have a rotation of the sacrum (or in fact any vertebrae), a coupled (combined) motion with side bending also occurs; the general rule (according to the current research) is that the side bending motion will be coupled to the opposite side of the sacral rotation. This follows what is typically known as a *Type I* or *neutral mechanic* (explained in detail in Chapter 6), in which the rotation and side bending are coupled to the opposite side; for instance, the sacrum can perform a side bending motion to the left side, but it will rotate to the opposite side (to the right side in this case).

Consider the following example to illustrate what I am trying to say. If the *left* side of the sacrum goes forward into anterior nutation, it will rotate to the *right* side (the sacral base will palpate deeper on the left side) and will also side bend to the *left* (Figure 2.9). However, the *right* side of the sacrum will also rotate to the *right* side, but this time the sacral base will be in a posterior nutation position (counter-nutation, as the sacral base will now palpate shallow on the right side).

Figure 2.9. Example of a unilateral motion of the sacrum.

The movement discussed above, in which you have a rotation to one side and a side bending motion to the other, is also known as a *sacral torsion*; this specific type of sacral movement is considered to occur around an oblique axis (see figure 2.10).

Sacral Axis

There are approximately six types of sacral axis (Figure 2.10):

- Superior transverse axis
- Middle transverse axis
- Inferior transverse axis
- Left oblique axis
- Right oblique axis
- Vertical axis

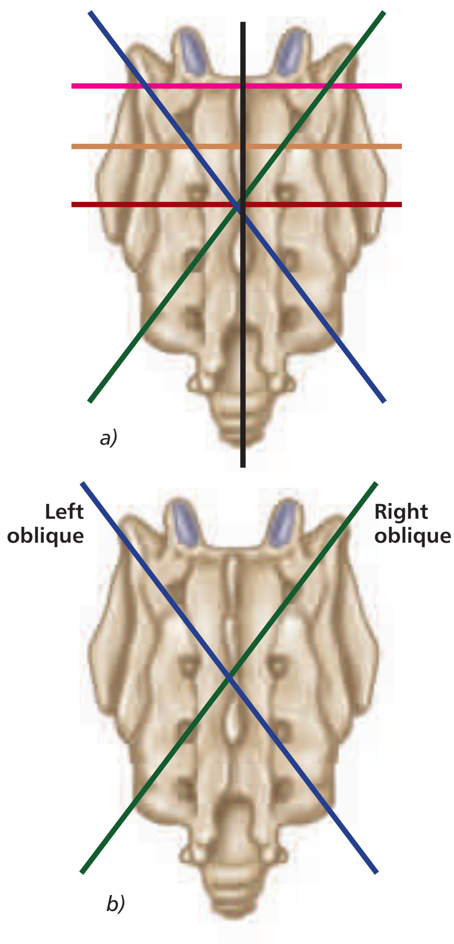


Figure 2.10. (a) Sacral axis, (b) Left oblique axis and right oblique axis.

It is not within the scope of this book to cover all the different sacral axis variations. For this text, however, the one of particular relevance is the middle transverse axis (MTA), because sacral dysfunctions are palpated and treated about this horizontal axis, according to Mitchell terminology. Moreover, this axis is considered to undergo a transformation during the gait cycle into the *oblique axis*, which is the specific axis that will be focused on in this text.

Oblique Axis

It has been suggested by some authors that there is a left oblique axis and a right oblique axis (see Figure 2.10(b)). The *left oblique axis* runs through the left sacral base and continues through the right inferior lateral angle (ILA); the *right oblique axis* runs through the right sacral base and continues through the left ILA.

In Chapter 3 I will take you through exactly how the oblique axis is utilized in combination with the movements of the kinetic chain as we perform sacral motion during the walking/gait cycle. For now, however, we will focus on the two natural physiological motions that the sacrum is capable of: "left rotation on the left oblique axis," which is typically called a *left-on-left* (L-on-L) sacral torsion, and a "right rotation on the right oblique axis," commonly known as a *right-on-right* (R-on-R) sacral torsion.

There are, however, also two non-physiological motions of the sacrum: "left rotation on the right oblique axis," which is typically called a *left-on-right* (L-on-R) sacral torsion, and a "right rotation on the left oblique axis," commonly known as a *right-on-left* (R-on-L) sacral torsion.

When authors mention the word "sacral torsion," they can mean one of two things: a naturally occurring motion of the sacrum that is performed, for example, during the gait cycle (Chapter 3 will explain this); or a dysfunction of the sacrum, in that it becomes fixed in this specific type of position or torsion.

Physiological Motions (Anterior Motion Fixation/Nutation)

Before we look at sacral torsions, let's just remind ourselves of the *neutral* position of the sacrum, as shown in Figure 2.11(a) and indicated by the model in Figure 2.11(b).

Figure 2.11. (a) Neutral position of the sacrum.

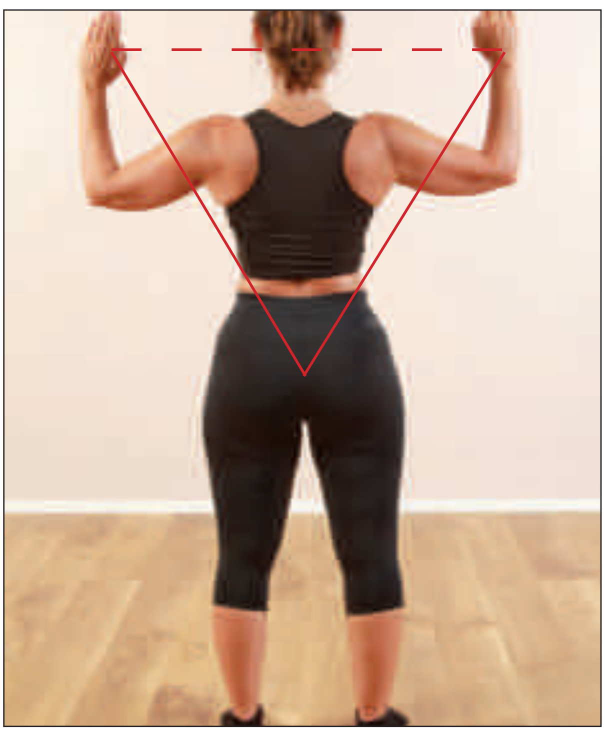


Figure 2.11. (b) Neutral position of the sacrum, as indicated by the model.

Left-on-Left (L-on-L)

Let's discuss a L-on-L sacral motion/torsion a bit further: it relates to the sacral bone being in a position of left rotation on the left oblique axis. This will be specific to the case where the sacrum has rotated to the left side, so the sacral sulcus (the area that is naturally formed by the junction of the sacral base with the corresponding ilium) will palpate as deep on the right. Moreover, the ILA as well as the sacral sulcus will palpate as posterior (shallow) on the left side, which will indicate that the *right* side of the sacrum has anteriorly nutated to the *left*, as shown in Figure 2.12(a).

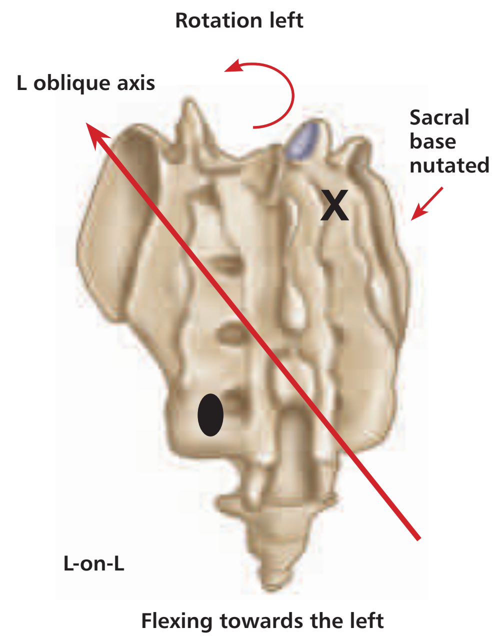


Figure 2.12. (a) Left-on-left (L-on-L) sacral motion/torsion. X = Anterior or deep. ⬮ = Posterior or shallow.

The specific motion of a L-on-L sacral torsion is demonstrated in Figure 2.12(b).

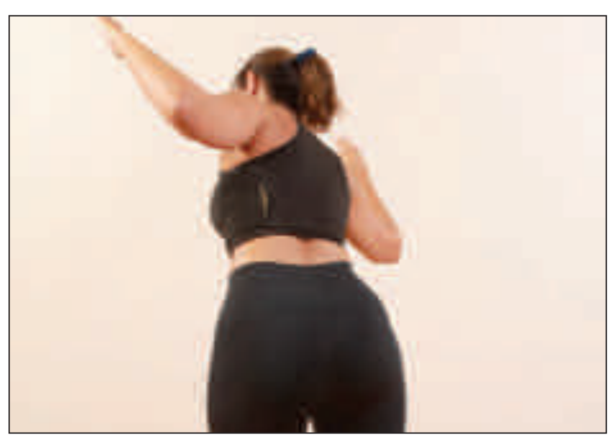


Figure 2.12. (b) L-on-L sacral torsion, as demonstrated by the model—sacral nutation is shown on the right side.

Right-on-Right (R-on-R)

A R-on-R sacral torsion relates to a right rotation on the right oblique axis. This will be specific to a sacrum that has rotated to the right side, so the sacral sulcus will palpate as deep on the left side. The ILA and the sacral sulcus will palpate as posterior (shallow) on the right, which will indicate that the *left* side of the sacrum has anteriorly nutated to the *right*, as shown in Figure 2.13(a).

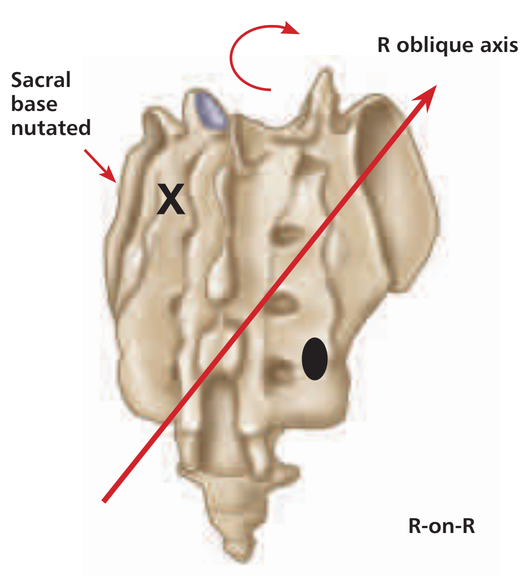


Figure 2.13. (a) Right-on-right (R-on-R) sacral motion/torsion. X = Anterior or deep. ⬮ = Posterior or shallow.

The model in Figure 2.13(b) is demonstrating the specific motion of a R-on-R sacral torsion.

Figure 2.13. (b) R-on-R sacral torsion, as demonstrated by the model—sacral nutation is shown on the left side.

Physiological Summary

As I have already mentioned, L-on-L and R-on-R sacral torsions are naturally occurring motions around the sacrum, although these specific motions can be fixed in a position of nutation. For example, if you have a dysfunctional position, say a L-on-L sacral torsion, then the sacrum is capable of performing this movement, as it is already fixed in this position and is potentially capable of rotating back to a "neutral" position. However, it is unable to perform a "R-on-R" sacral torsion due to the fact that the left side of the sacrum is unable to counter-nutate (posterior nutation), as this side (left) is held in a fixed position of anterior nutation.

You will read in Chapter 3 that most of the activity of our musculoskeletal system will involve the walking/gait cycle. As humans, we especially need to be able to maintain ongoing L-on-L and R-on-R sacral (torsion) motions, since these are of paramount importance to enable us to ambulate normally through the gait cycle. If the sacrum cannot perform these naturally occurring sacral torsions (motion), dysfunction occurs as a consequence.

Non-Physiological Motions (Posterior Motion Fixation/Counter-Nutation)

Non-physiological motions of the sacrum are a little bit more complex to grasp, as they are considered to be *unnatural* motions that occur around an oblique axis of the sacrum. If you do happen to find this type of posterior sacral dysfunction with your patients, it often tends to be caused by the lumbar spine/trunk being placed into a position of increased (forced) flexion with a combined movement of rotation (as in the motion of rotating your body to pick up a heavy weight from the floor).

It may take you a while to think about and understand this next concept but I will try my best to explain this in a relatively simple way, even though many people will still have difficulty understanding what it is I am trying to portray due to the natural complexity of this fascinating area.

Before we start I would like you to think of this motion simply as a backward/posterior torsion, whereas the other two types I mentioned in the earlier paragraphs are forward/anterior torsions.

Left-on-Right (L-on-R)

A *L-on-R sacral torsion* relates to a left rotation on the right oblique axis, and this will be specific to the case where the sacrum has rotated to the *left* side. However, because of the posterior motion of the left side of the sacrum, the sacral sulcus will now palpate as shallow on the *left*, and the ILA will palpate as posterior (shallow) on the *left*; this will indicate that the *left* side of the sacrum has counter-nutated or posteriorly nutated, as shown in Figure 2.14(a).

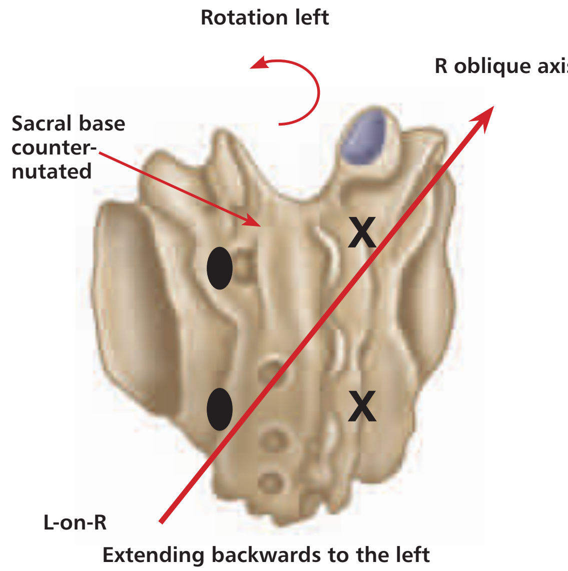


Figure 2.14. (a) Left-on-right (L-on-R) sacral torsion. X = Anterior or deep. ⬮ = Posterior or shallow.

This specific motion of a L-on-R sacral torsion can be seen in Figure 2.14(b), as demonstrated by the model.

Figure 2.14. (b) L-on-R sacral torsion, as demonstrated by the model—sacral counter-nutation is shown on the left side.

Right-on-Left (R-on-L)

It follows that a *R-on-L sacral torsion* must be the opposite of a L-on-R sacral torsion; thus, the sacral torsion this time relates to a right rotation on the left oblique axis, and this will be specific to the sacrum having rotated to the *right* side. Because of the posterior motion of the right side of the sacrum, however, the sacral sulcus will now palpate as "shallow" on the *right*, and the ILA will palpate as posterior (shallow) on the *right.* This will indicate that the *right* side of the sacrum has counter-nutated, or (if easier to understand) that the sacrum has posteriorly nutated (think of this simply as a backward motion), as shown in Figure 2.15(a).

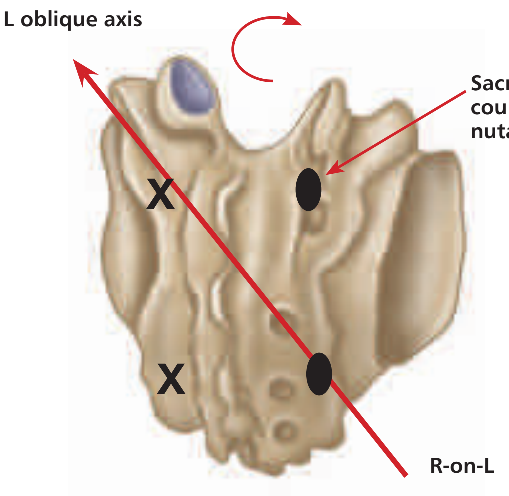


Figure 2.15. (a) Right-on-left (R-on-L) sacral torsion. X = Anterior or deep. ⬮ = Posterior or shallow.

Figure 2.15(b) illustrates the specific motion of a R-on-L sacral torsion, as demonstrated by the model.

Figure 2.15. (b) R-on-L sacral torsion, as demonstrated by the model—sacral counter-nutation is shown on the right side.

Non-Physiological Summary

What I would like to do now is give a brief review of the main points discussed above, so that you can better understand these specific types of dysfunction. We know that L-on-R and R-on-L sacral torsions are *unnatural* motions of the sacrum, hence their being termed *non-physiological*. These specific motions can be fixed in a position of counter-nutation or a backward torsion. For example, if you have a dysfunctional position of a L-on-R sacral torsion, the sacrum is capable of performing this backward type of movement, as it is already fixed in that position. The sacrum is, however, unable to perform the normal physiological motion of a L-on-L or a R-on-R sacral torsion, because of the fact that the *left* side of the sacrum is unable to nutate, since it is held in a fixed position. Another way of thinking about this is that the left side of the sacrum cannot perform the motion of anterior nutation, or simply go forward on the left, as it is held backward in a fixed position of counter-nutation or posterior nutation.

Sacral Torsions Summary

Tables 2.1 and 2.2 summarize the physiological and non-physiological motions of the sacrum. You will notice that the tables contain extra components, namely the position of the 5th lumbar vertebra, seated flexion test, lumbar spring test, sphinx test, lumbar lordosis curvature, and position of the medial malleolus.

All of these will be explained in more detail in later chapters, especially Chapter 12, but have been mentioned here because my aim in this chapter is to whet your appetite to continue reading. For now, I just wanted you to be aware of all the different types of physiological and non-physiological motion that the sacrum is capable of before we progress through the rest of the chapters.

	L-on-L sacral torsion Forward/nutation	**R-on-R sacral torsion Forward/nutation**
Deep sacral sulcus (neutral)	Right	Left
Shallow sacral sulcus (neutral)	Left	Right
ILA posterior	Left	Right
L5 rotation	Right—ERS(R)	Left—ERS(L)
Seated flexion test	Right	Left
Lumbar spring	Negative	Negative
Sphinx test	Sacral sulci level	Sacral sulci level
Lumbar lordosis	Increased	Increased
Medial malleolus (leg length)	Short left	Short right

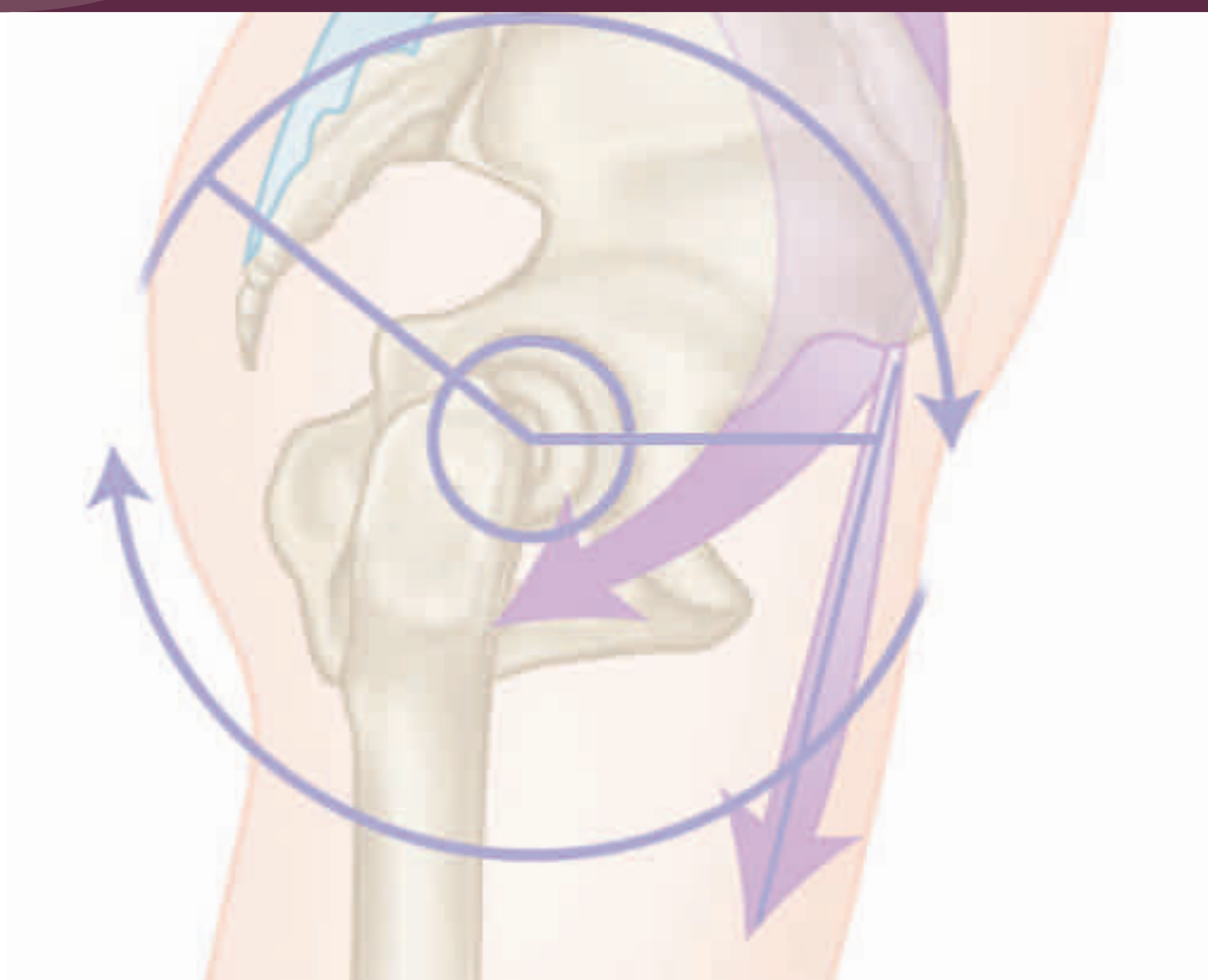
Table 2.1. Normal physiological motion: anterior/forward sacral torsions.

	L-on-R sacral torsion Backward/counter-nutation	**R-on-L sacral torsion Backward/counter-nutation**
Deep sacral sulcus (neutral)	Right	Left
Shallow sacral sulcus (neutral)	Left	Right
ILA posterior	Left	Right
L5 rotation	Right—FRS(R)	Left—FRS(L)
Seated flexion test	Left	Right
Lumbar spring	Positive	Positive
Sphinx test	Left sacral sulcus shallow (right sacral sulcus deeper)	Right sacral sulcus shallow (left sacral sulcus deeper)
Lumbar lordosis	Decreased	Decreased
Medial malleolus (leg length)	Short left	Short right

Table 2.2. Non-physiological motion: posterior/backward sacral torsions.

3

Sacroiliac Joint Stability, Muscle Imbalances, and the Myofascial Slings



As the incidence of pelvic and lower back pain continues to increase, we will need to look at and understand the muscular relationships that affect the core and lumbo–pelvic–sacral stability. We will then have to decide how to incorporate this knowledge into an assessment and treatment plan, especially for patients and athletes who present with pain associated with the area of the pelvic girdle and lower back.

There are two main factors that affect the stability of the pelvis (or to be more precise the sacroiliac joint (SIJ)): form closure and force closure. These two mechanisms collectively assist in a process known as the *self-locking mechanism*.

Form closure arises from the anatomical alignment of the bones of the innominate and the sacrum, where the sacrum forms a kind of keystone between the wings of the pelvis. The SIJ transfers large loads and its shape is adapted to this task. The articular surfaces are relatively flat, which helps to transfer compression forces and bending movements. However, a relatively flat joint is vulnerable to shear forces. The SIJ is protected from these forces in three ways. First, the sacrum is wedge (triangular) shaped and thus is stabilized between the innominate bones, similarly to a keystone in a Roman arch, and is kept in a state of "suspension" by the ligaments acting upon it. Second, in contrast to other synovial joints, the articular cartilage is not smooth but rather irregular (think back to Chapter 1). Third, a frontal dissection through the SIJ reveals cartilage-covered bone extensions protruding into the joint—the so-called "ridges" and "grooves." They seem rather irregular, but are in fact complementary to each other, and this unusual irregularity is very relevant as it serves to stabilize the SIJ when compression is applied.

According to Vleeming et al. (1990a), after puberty most individuals develop a crescent-shaped ridge running the entire length of the iliac surface with a corresponding depression on the sacral side; this complementary ridge and groove are now believed to lock the surfaces together and increase stability of the SIJ.

If the articular surfaces of the sacrum and the innominate bones fitted together with perfect form closure, mobility would be practically impossible. However, form closure of the SIJ is not perfect and mobility—albeit small—is possible, and therefore stabilization during loading is required. This is achieved by increasing compression across the joint at the moment of loading; the anatomical structures responsible for this compression are the ligaments, muscles, and fasciae. The mechanism of compression of the SIJ by these additional forces is what is commonly called *force closure*. When the SIJ is compressed, friction of the joint increases and consequently reinforces form closure, as shown in Figure 3.1. According to Willard et al. (2012), force closure reduces the joint's "neutral zone," thereby facilitating stabilization of the SIJ.

Force closure is accomplished as follows. The first method is by nutation of the sacrum, which is achieved either by anterior motion of the sacral base or by posterior rotation of the innominate bone. These two types of motion result in a tightening of the sacrotuberous, sacrospinous, and interosseous ligaments; this tightening assists in activating the force closure mechanism, thereby increasing the compression of the SIJ. Counter-nutation, on the other hand, decreases the stability of the SIJ because of the reduced tension in the above-mentioned ligaments.

Cohen (2005) states that because the ilium and sacrum only meet at approximately one-third of their surfaces, the associated ligaments provide the rest of the stability between these bones.

In the second method, force closure is assisted by the activation/contraction of the inner and outer core muscles (local and global muscle systems), as you will read later on in this chapter.

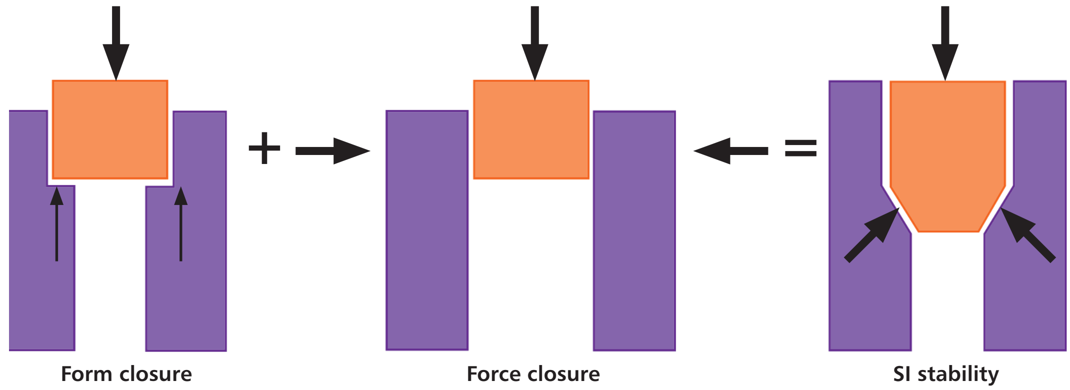


Figure 3.1. The relationship between form/force closure and sacroiliac stability.

The terms *form closure* and *force closure* delineate the active and passive components of this self-locking mechanism and were first identified by Vleeming et al. (1990a, 1990b). Below is a quote from Vleeming et al. (1995) that I personally believe explains the above text.

"Shear in the sacroiliac joints is prevented by the combination of specific anatomical features (form closure) and the compression generated by muscles and ligaments that can be accommodated to the specific loading situation (force closure). If the sacrum would fit the pelvis with perfect form closure, no lateral forces would be needed. However, such a construction would make mobility practically impossible."

Sacroiliac Stability

Several ligaments, muscles, and fascial systems contribute to force closure of the pelvis: these are collectively referred to as the *osteo-articular-ligamentous system*. Recall that when the body is working efficiently, the shear forces between the innominate bones and the sacrum are adequately controlled, and loads can then be transferred between the trunk, pelvis, and legs.

Vleeming and Stoeckart (2007) mention that various muscles are involved in force closure of the SIJ, and that even muscles such as the rectus femoris, sartorius, iliacus, Gmax, and hamstrings have adequate lever arms to influence movement in the SIJ. The effect of these muscles is dependent on open or closed kinematic movements, and whether the pelvis is sufficiently braced.

As you will read shortly, and also in later chapters, there is one muscle in particular that plays a highly significant role in stabilizing the SIJs—this muscle is the Gmax. Some of the Gmax fibers merge and attach onto the sacrotuberous ligament as well as onto a connective tissue structure known as the *thoracolumbar fascia*. Vleeming et al. (1989a) demonstrated this fact on 12 cadaver dissections; they found that the Gmax muscle was directly attached to the sacrotuberous ligament in all cases.

The Gmax connects, via the thoracolumbar fascia, to the contralateral latissimus dorsi to form what is known as the *posterior oblique myofascial sling* (see section "The Outer Core Unit: The Integrated Myofascial Sling System (Global System)" later in this chapter). It has been shown that weakness, or possibly a misfiring sequence, of the Gmax will predispose the SIJ to injury by decreasing the function of this (posterior oblique) myofascial sling. A weakness or misfiring of the Gmax is a potential cause of a compensatory overactivation of the contralateral latissimus dorsi; walking and running (gait cycle, explained in Chapter 4) impose high loads on the SIJ, so this weight-bearing joint will need to be self-stabilizing in order to reduce the effect of the altered compensatory mechanism.

Research has shown that sacral nutation (a nodding type of movement of the sacrum between the innominate bones) is the best position for the pelvic girdle to be at its most stable. As I have already explained in earlier chapters, nutation occurs when moving (for example) from a sitting position to standing, and full nutation occurs during forward or backward bending of the trunk. This motion of sacral nutation tightens the major ligaments (sacrotuberous, sacrospinous, and interosseous) of the posterior pelvis, and the resulting tension increases the compressive force across the SIJ. The increased tension provides the required stability that is needed by the SIJ during the gait cycle as well as when simply rising from a sitting to a standing position.

Vleeming et al. (1989b) showed how load application to the sacrotuberous ligament, either directly to the ligament or through its continuations with the long head of biceps femoris or the attachments of the Gmax, significantly diminishes forward rotation of the sacral base. They demonstrated that this increases the coefficient of friction, thus decreasing movement of the SIJ by force closure.

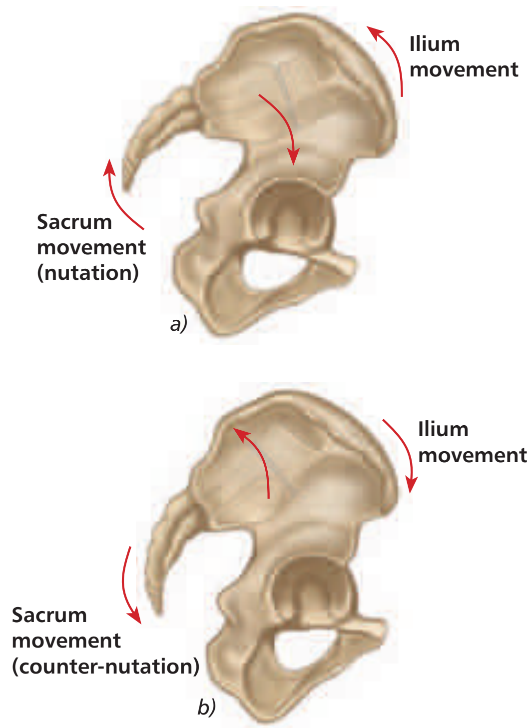


Figure 3.2. (a) Posterior pelvic rotation and sacral nutation. (b) Anterior pelvic rotation and sacral counter-nutation.

Sacral Nutation and Counter-Nutation

I find it very beneficial at certain times, especially for you the reader, to try to discuss alternative ways of explaining a relatively complex motion. I therefore thought I would introduce an opinion by another author, Evan Osar (2012), who states that *nutation* is the anterior inferior motion of the sacral base, while *counter-nutation* is the posterior superior motion of the sacral base. Nutation is necessary for the locking of the SIJ during unilateral stance, as shown in Figure 3.2(a). The inability to nutate the sacrum is a leading cause of unilateral stance instability and one of the causes of the classic Trendelenburg gait. Counter-nutation, on the other hand, is necessary in order to unlock the SIJ to allow anterior rotation of the innominate and extension of the hip joint, as shown in Figure 3.2(b). The inability to unlock or counter-nutate the sacrum leads to compensatory increases in lumbopelvic flexion, which in turn lead to and perpetuate lumbar instability.

Force Closure Ligaments

The main ligamentous structures that influence force closure (Figure 3.3) are: (1) the sacrotuberous ligament, which connects the sacrum to the ischium and has been termed the *key* or *lead* ligament; and (2) the long dorsal sacroiliac ligament, which connects the 3rd and 4th sacral segments to the PSIS and is also known as the *posterior sacroiliac ligament*.

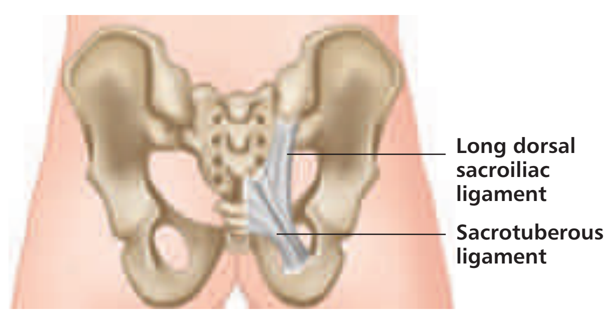


Figure 3.3. Sacrotuberous ligament (key) and the long dorsal sacroiliac ligament.

Ligaments can increase articular compression when they are tensed or lengthened by the movement of the bones to which they attach, or when they are tensed by the contraction of muscles that insert onto the bones.

Tension in the sacrotuberous ligament can be increased in one of three ways:

1. Posterior rotation of the innominate bone relative to the sacrum.
2. Nutation of the sacrum relative to the innominate bone.
3. Muscular contraction of any one of the four muscles that have a direct attachment to the sacrotuberous ligament, namely biceps femoris, piriformis, Gmax, and multifidus.

The main ligamentous tissue to restrain counter-nutation of the sacrum, or anterior rotation of the innominate, is the long dorsal sacroiliac ligament (posterior sacroiliac ligament). This is a less stable position (compared with the position of nutation) for the pelvis to resist horizontal and/or vertical loading, since the SIJ is under less compression and is not self-locked. The long dorsal ligament is commonly a source of pain and can be palpated just below (inferior to) the level of the PSIS.

By themselves, ligaments cannot maintain a stable pelvis—they rely on several muscle systems to assist them. There are two important groups of muscles that contribute to stability of the lower back and pelvis: collectively they are called the *inner unit* (core) and the *outer unit* (myofascial sling systems). The inner unit consists of the transversus abdominis (TVA), multifidus, diaphragm, and muscles of the pelvic floor—also collectively known as the *core*, or *local stabilizers*. The outer unit consists of several "slings," or systems of muscles (global stabilizers and mobilizers that are anatomically connected and functionally related). The inner and outer units will be discussed later on in this chapter.

Force Couple

Definition: A *force couple* is a situation where two forces of equal magnitude, but acting in opposite directions, are applied to an object and pure rotation results, as mentioned by Abernethy et al. (2004).

Any altered positioning of the pelvis caused by potential muscle imbalances will subsequently affect the rest of the kinetic chain. There are several force couples responsible for maintaining proper positioning and alignment of the pelvis. The force couples responsible for controlling the position of the pelvis in the sagittal and frontal planes are shown schematically in Figures 3.4(a–f) and 3.5.

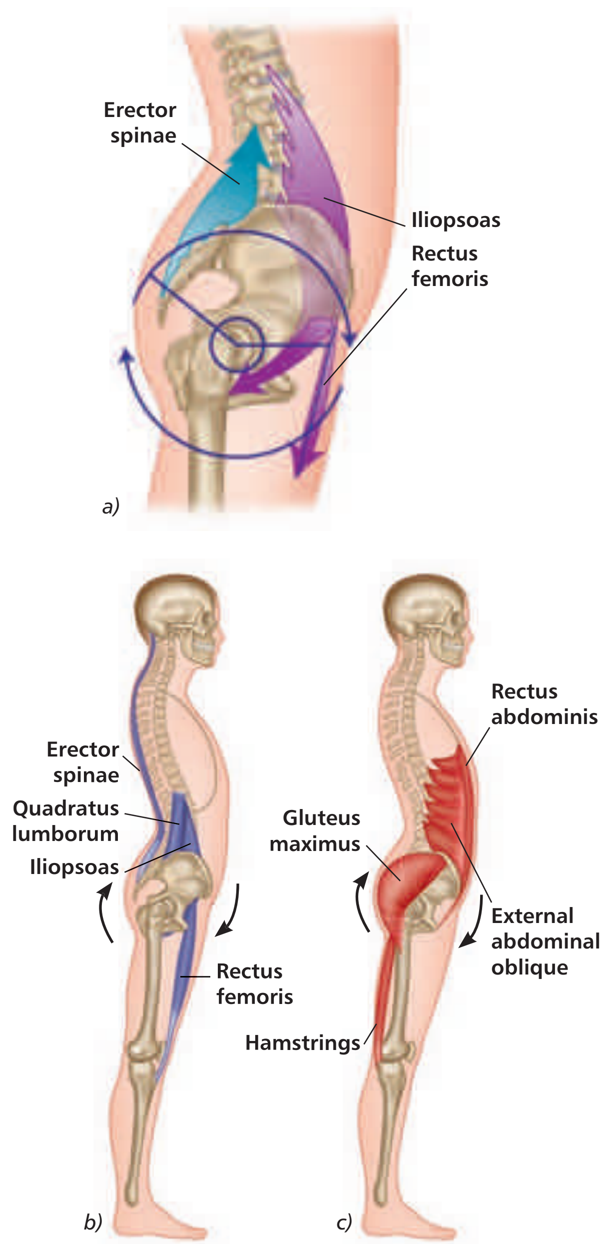


Figure 3.4. (a) Sagittal plane (anterior) pelvic force couple. (b) Anterior tilt: muscles held in a shortened position. (c) Anterior tilt: muscles held in a lengthened position.

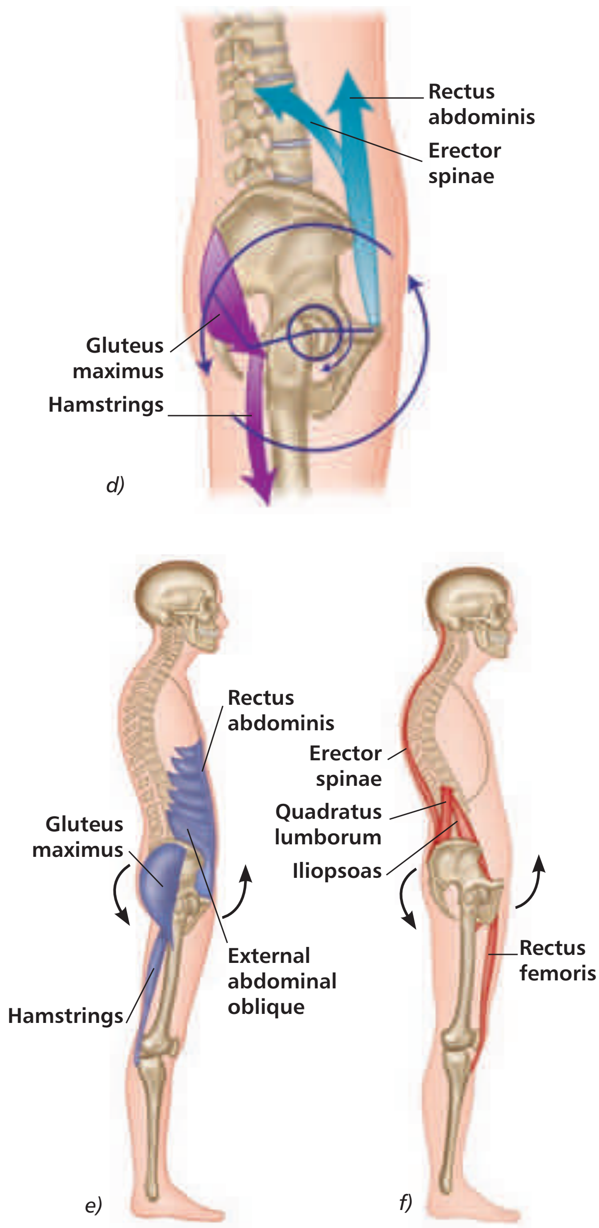


Figure 3.4. (d) Sagittal plane (posterior) pelvic force couple. (e) Posterior tilt: muscles held in a shortened position. (f) Posterior tilt: muscles held in a lengthened position.

Figure 3.5. Frontal plane (lateral) pelvic force couples.

Posture

Definition: *Posture* is the attitude or position of the body, as discussed by Thomas (1997).

According to Martin (2002), posture should fulfill three functions:

1. Maintain the alignment of the body's segments in any position: supine, prone, sitting, all fours, and standing.
2. Anticipate change to allow engagement in voluntary, goal-directed movements, such as reaching and stepping.
3. React to unexpected perturbations or disturbances in balance.

From the above, it can be seen that posture is an active as well as a static state, and that it is synonymous with balance. Optimal posture must be maintained at all times, not only when holding static positions (e.g. sitting and standing) but also during movement.

If optimal posture and postural control are to be encouraged during exercise performance, the principles of good static posture must be fully appreciated. Once these are understood, poor posture can be identified and corrective strategies adopted.

- *Good posture* is the state of muscular and skeletal balance that protects the supporting structures of the body against injury or progressive deformity, irrespective of the attitude (e.g. erect, lying, squatting, or stooping) in which these structures are working or resting.
- *Poor posture* is a faulty relationship of the various parts of the body, producing increased strain on the supporting structures, and resulting in less efficient balance of the body over its base of support.

Poor Posture

Poor posture may be a result of many different contributing factors. It may be caused by trauma suffered by the body, some form of deformity within the musculoskeletal system, or even faulty loading. Because sitting has become a position maintained by our bodies for long periods of time (possibly 8+ hours), most people in today's society are losing the fight against gravity and altering their center of gravity (COG). With correct posture, your postural muscles are fairly inactive and energy efficient, only responding to disruptions in balance in order to maintain an upright position. As you move away from an ideal alignment, postural muscle activity therefore increases, thus leading to higher energy expenditure.

Pain Spasm Cycle

Ischemia will be a primary source of pain in the initial stages of poor posture. The blood flow through a muscle is inversely proportional to the level of contraction or activity, reaching almost zero at 50–60% of contraction. Some studies have indicated that the body is not able to maintain homeostasis with a sustained isometric contraction of over 10%.

Consider the following example: the weight of the head is approximately 7% of total body weight (shoulders and arms are around 14%). This means that for a person weighing 176lbs (80kg), the head will weigh around 11–13lbs (5 to 6kg). If the head and shoulders move forward, out of ideal alignment, the activation of the neck extensors will increase dramatically, resulting in restricted blood flow. Previous authors have stated that for every inch of forward head posture, the weight of the head on the spine can increase by approximately 10lb (4.5kg). For example, if the weight of the head is normally 10lb (4.5kg), it will now potentially weigh 20lb (9kg) for just a 1" (2.5cm) increase in forward head posture, 30lb (13.5kg) for a 2" (5cm) increase, and an unbelievable 40lb (18kg) if the head translates 3" (7.5cm), as shown in Figure 3.6(a).

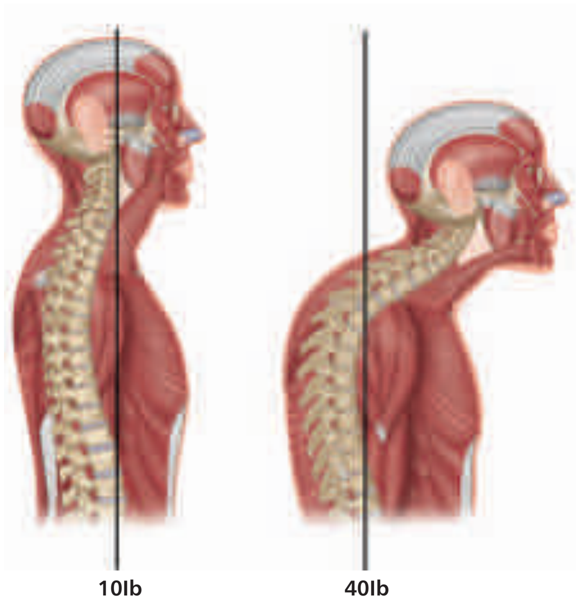


Figure 3.6. (a) The result of a forward head posture.

This prolonged isometric contraction will force the muscles into anaerobic metabolism and increase lactic acid and other irritating metabolite accumulation. If adequate rest is not given, a reflex contraction of the already ischemic muscles may be initiated. This person will have now entered the pain spasm cycle (Figure 3.6(b)).

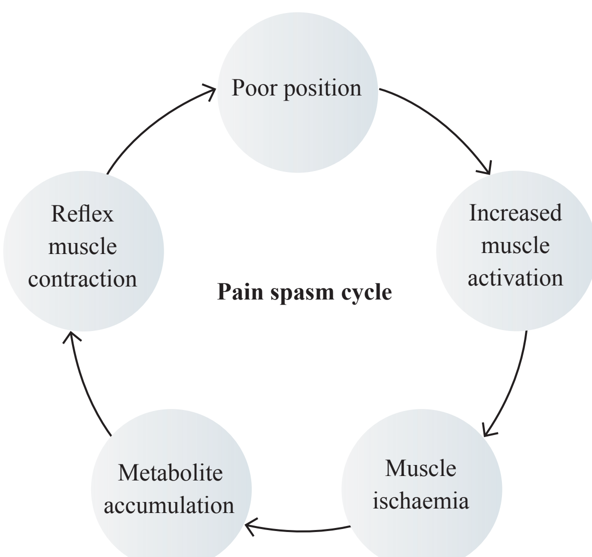


Figure 3.6. (b) Pain spasm model.

The neuromuscular system, as we know, is made up of *slow-twitch* and *fast-twitch* muscle fibers, each having a different role in the body's function. Slow-twitch fibers (Type I) are active in sustained low-level activity, such as maintaining correct posture, whereas fast-twitch fibers (Type II) are used for powerful, gross movements. Muscles can also be broken down into two further categories—*tonic* (or *postural*) and *phasic*.

Tonic (Postural) and Phasic Muscles

Janda (1987) identified two groups of muscles on the basis of their evolution and development. Functionally, muscles can be classified as *tonic* or *phasic*. The tonic system consists of the flexors, which develop later on to become the dominant structure. Umphred et al. (2001) identified that the tonic muscles are involved in repetitive or rhythmic activity and are activated in flexor synergies, whereas the phasic system consists of the extensors and emerges shortly after birth. The phasic muscles work eccentrically against the force of gravity and are involved in extensor synergies. The division of muscles into predominantly phasic and predominantly postural is given in Table 3.1.

Predominantly postural muscles	Predominantly phasic muscles
Shoulder girdle	
Pectoralis major/minor Levator scapulae Upper trapezius Biceps brachii Neck extensors: Scalenes / Cervical erectors / Sternocleidomastoid	Rhomboids Lower trapezius Mid trapezius Seratus anterior Triceps brachii Neck flexors: Supra- and infrahyoid / Longus colli
Lower arm	
Wrist flexors	Wrist extensors
Trunk	
Lumbar and cervical erectors Quadratus lumborum	Thoracic erectors Abdominals
Pelvis	
Biceps femoris / Semitendinosus / Semimembranosus Iliopsoas ITB Rectus femoris Adductors Piriformis / Tensor fasciae latae	Vastus medialis Vastus lateralis Gluteus maximus Gluteus minimus and medius
Lower leg	
Gastrocnemius / Soleus	Tibialis anterior / Peroneals

Table 3.1. Phasic and postural muscles of the body.

Previous authors have suggested that muscles which have a stabilizing function (postural) have a natural tendency to shorten when stressed, and that other muscles which play a more active/moving role (phasic) have a tendency to lengthen and can subsequently become inhibited (see Table 3.2). The muscles that tend to shorten have a primary postural role and are related to the potential inhibition weakness of the gluteal muscles (which you will read about later).

	Postural	Phasic
Function	Posture	Movement
Muscle type	Type I	Type II
Fatigue	Late	Early
Reaction	Shortening	Lengthening

Table 3.2. Lengthening and shortening of muscles.

There are some exceptions to the rule which states that certain muscles follow the pattern of becoming shortened while others become lengthened—some muscles are capable of modifying their structure. For example, some authors suggest that the scalene muscles are postural in nature, while others suggest that they are phasic. We know from specific testing, depending on what dysfunction is present within the muscle framework, that the scalenes can be found to be held in a shortened position and tight, but at other times they can be observed to be lengthened and weakened.

There is a distinction between postural and phasic muscles; however, many muscles can display characteristics of both and contain a mixture of Type I and Type II fibers. The hamstring muscles, for example, have a postural stabilizing function, yet are polyarticular (cross more than one joint) and are notoriously prone to shortening.

Postural Muscles

Also known as *tonic muscles*, the postural muscles have an antigravity role and are therefore heavily involved in the maintenance of posture. Slow-twitch fibers are more suited to maintaining posture: they are capable of sustained contraction but generally become shortened and subsequently tight.

Postural muscles are slow-twitch dominant because of their resistance to fatigue, and are innervated by a smaller motor neuron. They therefore have a lower excitability threshold, which means the nerve impulse will reach the postural muscle before the phasic muscle. With this sequence of innervation, the postural muscle will inhibit the phasic (antagonist) muscle, thus reducing its contractile potential and activation.

Phasic Muscles

Movement is the main function of phasic muscles. These muscles, which are often more superficial than postural muscles and tend to be polyarticular, are composed of predominantly Type II fibers and are under voluntary reflex control.

A shortened, tight postural muscle often results in inhibition of the associated phasic muscle, whose function becomes weakened as a result. The relationship between a tightness-prone muscle and an associated weakness-prone muscle is one way. As the tightness-prone muscle becomes tighter and subsequently stronger, this causes an inhibition of the weakness-prone muscle, resulting in its lengthening and consequent weakening: think about how this might affect the relationship, for example, between the iliopsoas and the gluteal muscles, or between the pectoralis major/minor and the rhomboids.

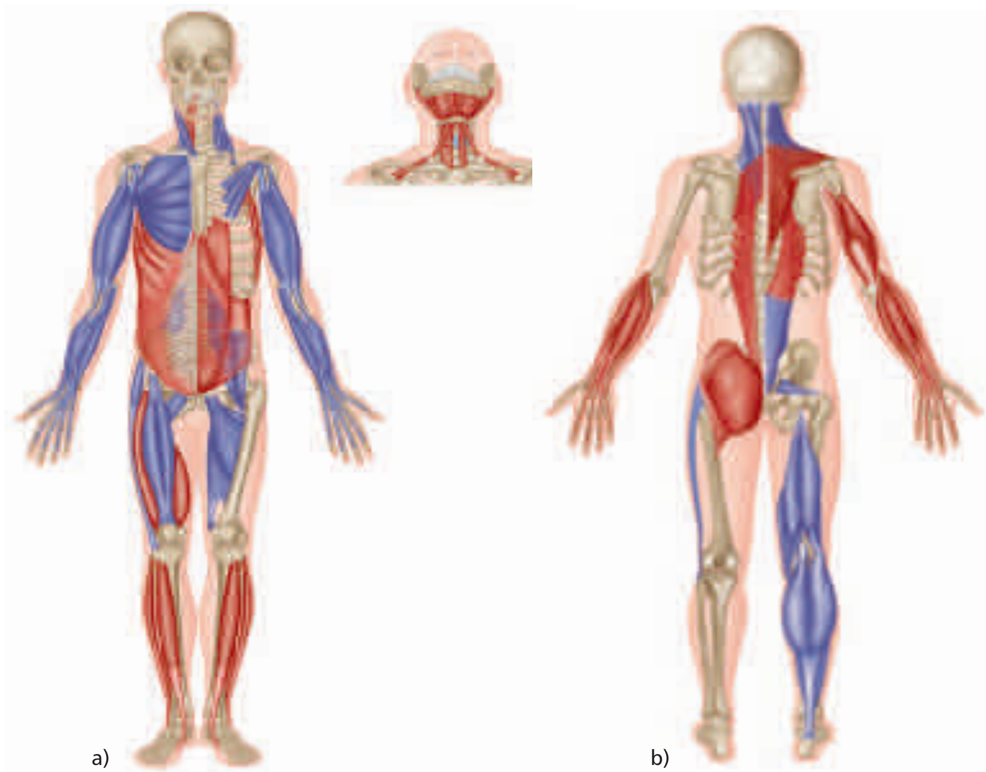


Figure 3.7. Postural and phasic muscles: (a) anterior view; (b) posterior view. The blue muscles are predominantly postural, and the red muscles predominantly phasic.

Muscle Activity Before and After Stretching

Let's take a look at some electromyography (EMG) studies of trunk muscle activity before and after stretching hypertonic muscles, in this case the erector spinae. In Table 3.3 the hypertonic erector spinae are indicated as being active during trunk flexion. After stretching, these muscles are suppressed both in trunk flexion (which allows greater activation of the rectus abdominis) and in trunk extension (dorsal raise).

Muscle	First recording			Second recording		
Rectus abdominis						
Erector spinae						

Table 3.3. EMG recordings of muscle activity. (Source: Hammer 1999)

Effects of Muscle Imbalance

The research results of Janda (1983) indicate that tight or overactive muscles not only hinder the agonist through Sherrington's law of reciprocal inhibition as stated by Sherrington (1907), but also become active in movements that they are not normally associated with. This is the reason why, when trying to correct a musculoskeletal imbalance, you would encourage *lengthening* of an overactive muscle by using a muscle energy technique (MET), prior to attempting to *strengthen* a weak elongated muscle (METs will be explained in Chapter 7).

Think about the following words before you continue reading:

"A *tight* muscle will pull the joint into a dysfunctional position and the *weak* muscle will allow this to happen."

One possible way to address this, therefore, is to simply apply the following rule: "lengthen before you strengthen."

If muscle imbalances are not addressed, the body will be forced into a compensatory position, which increases the stress placed on the musculoskeletal system, eventually leading to tissue breakdown, irritation, and injury. You are now in a vicious circle of musculoskeletal deterioration as the tonic muscles shorten and the phasic muscles lengthen (Table 3.4).

Muscle imbalances are ultimately reflected in posture. As mentioned earlier, postural muscles are innervated by a smaller motor neuron and therefore have a lower excitability threshold. Since the nerve impulse reaches the postural muscle before the phasic muscle, the postural muscle will inhibit the phasic (antagonist) muscle, thus reducing the contractile potential and activation.

When muscles are subject to faulty or repetitive loading, the postural muscles shorten and the phasic muscles weaken, thus altering their length–tension relationship. Consequently, posture is directly affected because the surrounding muscles displace the soft tissues and the skeleton.

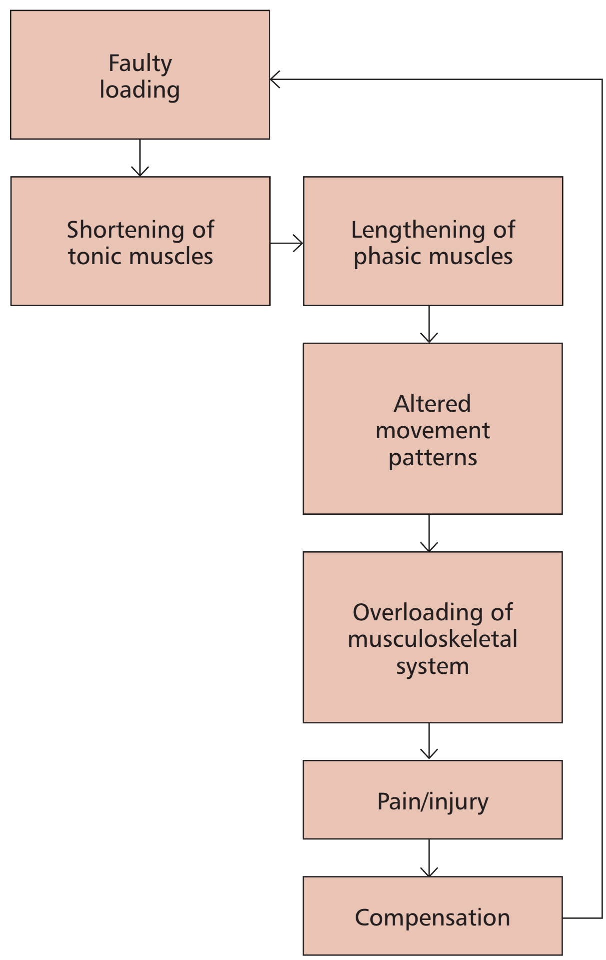


Table 3.4. The vicious circle of musculoskeletal deterioration.

Core Muscle Relationships

Inner Core Unit (Local System)

> **Definition:** *Static stability* is the ability to remain in one position for a long time without losing good structural alignment, as mentioned by Chek (1999).

Static stability is also often referred to as *postural stability*, although this might be somewhat misleading, since as Martin (2002) states: "… posture is more than just maintaining a position of the body such as standing. Posture is active, whether it is in sustaining an existing posture or moving from one posture to another."

The inner core unit (Figure 3.8) consists of:

- Transversus abdominis (TVA)
- Multifidus
- Diaphragm
- Muscles of the pelvic floor

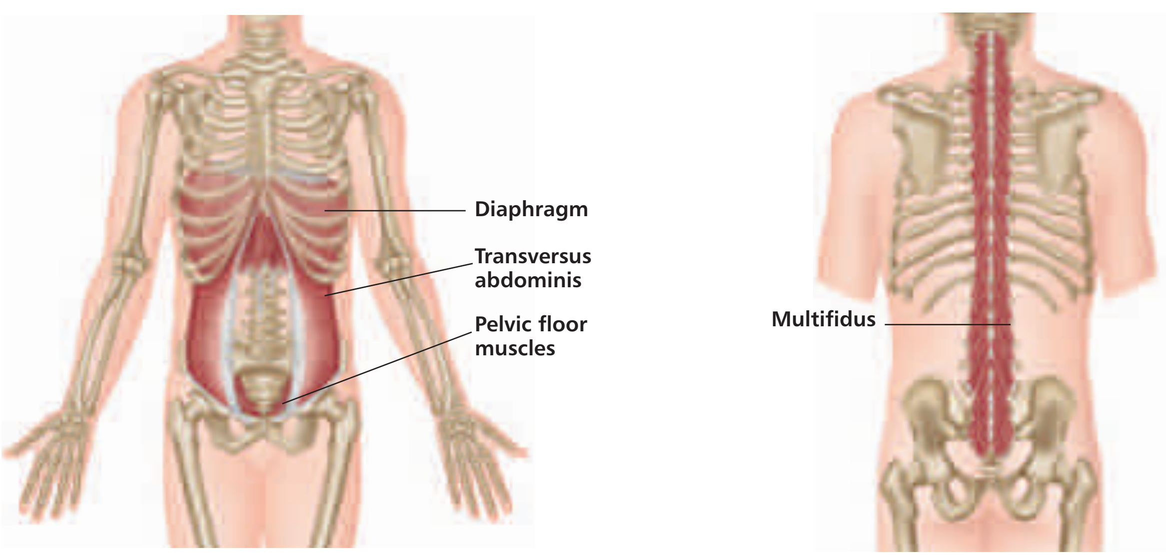
Only the TVA and multifidus will be covered in this book, as these muscles are specifically related to postural and phasic imbalances and are easily palpated by the physical therapist. Since the diaphragm and muscles of the pelvic floor are difficult to palpate, they will not be discussed here.

Transversus Abdominis

The transversus abdominis (TVA) is the deepest of the abdominal muscles. It originates at the iliac crest, inguinal ligament, lumbar fascia, and associated cartilage of the inferior six ribs, and attaches to the xiphoid process, linea alba, and pubis.

The main action of the TVA is to compress the abdomen via a "drawing-in" of the abdominal wall. This drawing-in is observable as a movement of the umbilicus (belly button) toward the spine. The muscle neither flexes nor extends the spine. Kendall et al. (2010) also state that "this muscle has no action in lateral flexion except that it acts to … stabilize the linea alba, thereby permitting better action by anterolateral trunk muscles [internal and external obliques]."

The TVA appears to be the key muscle of the inner unit. Richardson et al. (1999) found that in people without back pain, the TVA fired 30 milliseconds prior to shoulder movements and 110 milliseconds before leg movements. This corroborates the key role of the TVA in providing the stability necessary to perform movements of the appendicular skeleton. As the TVA contracts during inspiration it pulls the



Anterior view. Posterior view.

Figure 3.8: The inner core unit.

central tendon inferiorly and flattens, thereby increasing the vertical length of the thoracic cavity and compressing the lumbar multifidus.

Multifidus

The multifidus is the most medial of the lumbar back muscles, and its fibers converge near the lumbar spinous processes to an attachment known as the *mammillary process*. The fibers radiate inferiorly, passing to the TPs of the vertebrae that lie two, three, four, and five levels below. As well as some fibers uniting distally with the sacrotuberous ligament, those fibers that extend below the level of the last lumbar vertebra (L5) anchor to the ilium and the sacrum.

The multifidus is considered to be a series of smaller muscles, which are further divided into *superficial* and *deep* components. There is more muscle mass of the multifidus near the base of the sacrum than at the apex, especially filling the space between the PSISs rather than the ILAs.

The role of the multifidus in producing an extension force is essential to the stability of the lumbar spine, as well as functioning to resist forward flexion of the lumbar spine and the shear forces that are placed upon it. The multifidus muscle also functions to take pressure off the intervertebral discs, so that the body weight is evenly distributed throughout the whole vertebral column. The superficial muscle component acts to keep the vertebral column relatively straight, while the fibers of the deep muscle component contribute to the overall stability of the spine.

Richardson et al. (1999) identified the lumbar multifidus and the TVA as the key stabilizers of the lumbar spine. Both muscles link in with the thoracolumbar fascia to provide what Richardson et al. refer to as "a natural, deep muscle corset to protect the back from injury."

More recently, Richardson et al. (2002) investigated how these muscles impact the SIJ using the Echo Doppler (a diagnostic ultrasound device, which can show if specific muscles are contracting). They were able to demonstrate that when the TVA and multifidus co-contract, the stiffness of the SIJ increases, thereby proving that these muscles are essential to compressing the SIJ and stabilizing the joint under load (force closure) and also that it is critical that this compression occurs at just the right time.

Hydraulic Amplifier

Described by Osar (2012), the hydraulic amplifier effect occurs with the contraction of muscles within their fascial envelopes. All muscles are invested inside fascia and, as they contract, push out into the fascia, thus creating a stiffening effect around the joint. In the spine, contraction of the lumbar erector spinae and multifidus within the thoracolumbar fascia creates an extension force, assisting extension of the spine. Osar says that when the lumbosacral multifidus contracts, it broadens posteriorly into the lumbodorsal fascia (Figures 3.9 and 3.10).

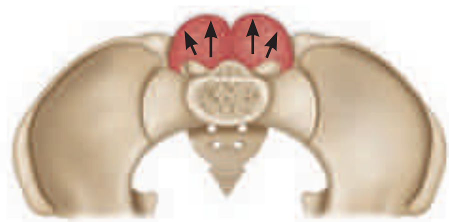


Figure 3.9. As the multifidus contracts, it pushes into the thoracolumbar fascia and, along with contraction of the TVA, provides intersegmental stability.

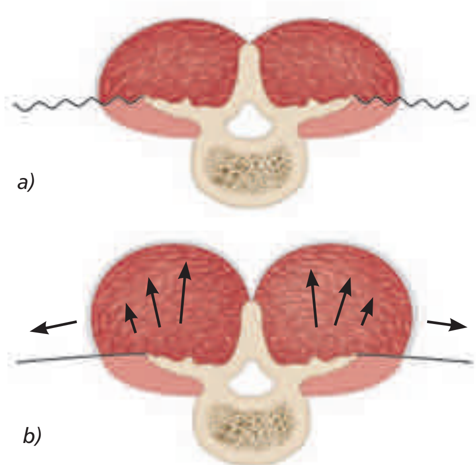


Figure 3.10. (a) The relaxed multifidus muscle in transverse section. (b) Co-contraction of the TVA and multifidus creates a stiffening tension on the thoracolumbar fascia, thereby providing intersegmental stability.

This effect is aided by contraction of the TVA, which pulls the thoracolumbar fascia tight around the contracting erector spinae and multifidus, thereby creating a stable column (Figure 3.11).

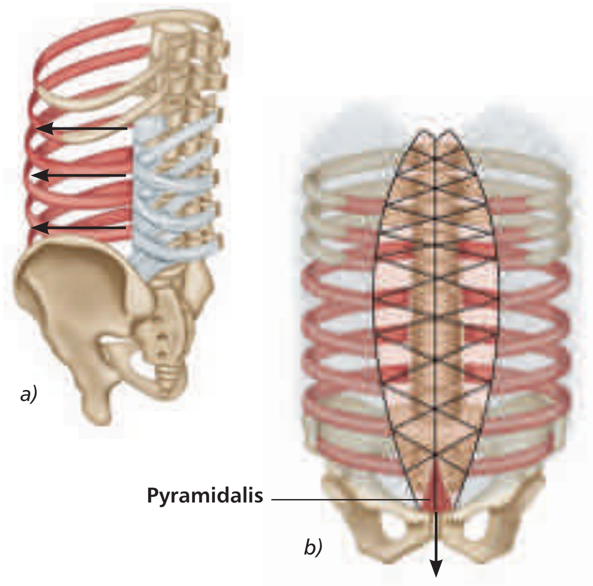


Figure 3.11. (a) As the TVA contracts, it tenses the thoracolumbar fascia, which allows the multifidus and lumbar erector spinae to contract against it and aid spinal elongation and stiffness. (b) Contraction of the pyramidalis tenses the linea alba (central tendon), creating a stable base for contraction of the TVA.

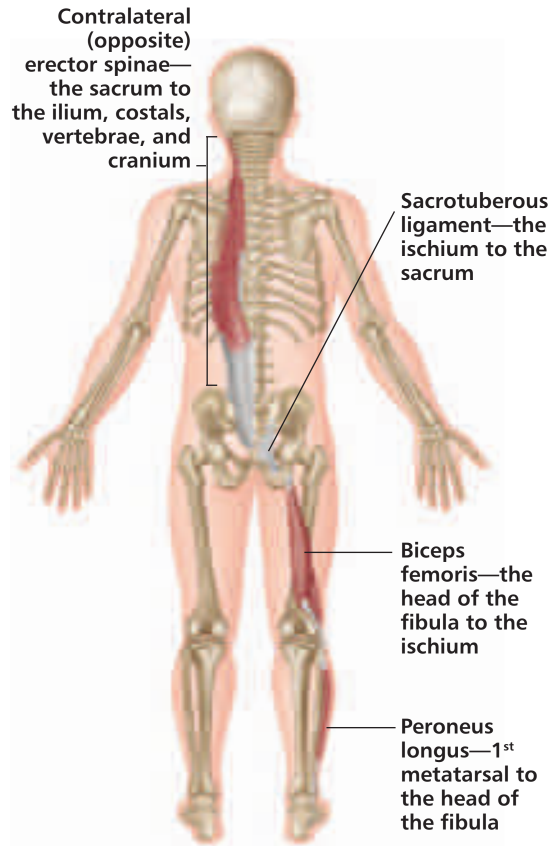


Figure 3.12. Posterior (deep) longitudinal sling.

Outer Core Unit (Global System)

The force closure muscles of the outer core unit consist of four integrated myofascial sling systems (Figures 3.12–3.15):

- Posterior (deep) longitudinal sling
- Lateral sling
- Anterior oblique sling
- Posterior oblique sling

These myofascial slings provide force closure and subsequent stability for the pelvic girdle; failure or even weakness of any of these slings to secure pelvic stability can lead to lumbopelvic pain and dysfunctions. Although the muscles of the outer core unit can be trained individually, effective force closure requires specific coactivation and release of these myofascial slings for optimal function and performance.

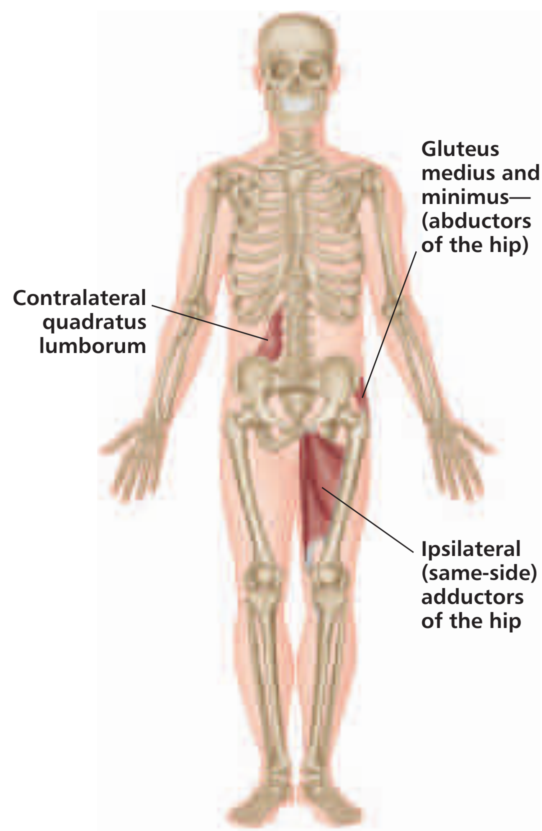


Figure 3.13. Lateral sling.

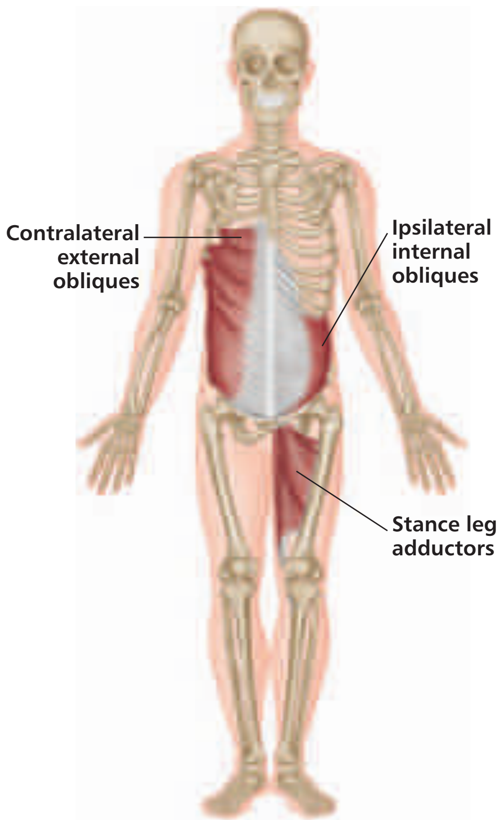


Figure 3.14. Anterior oblique sling.

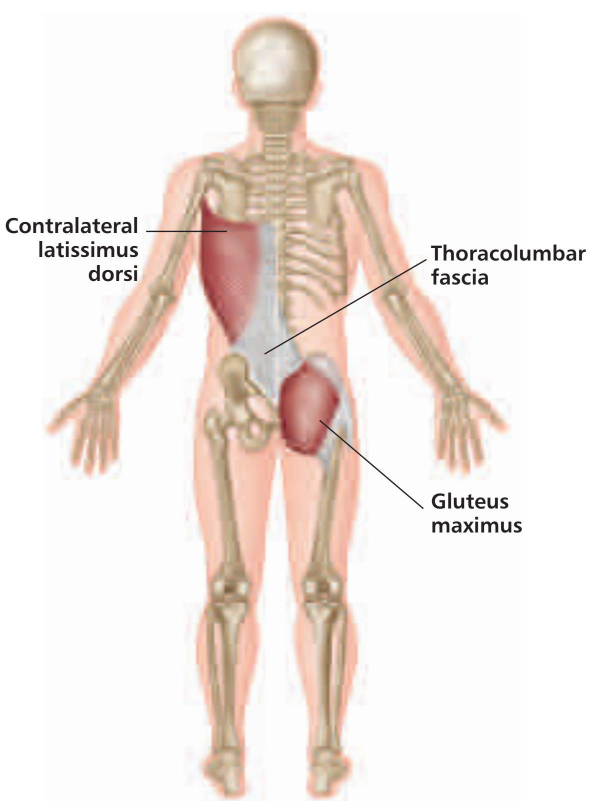


Figure 3.15. Posterior oblique sling.

The integrated myofascial sling system represents many forces and is composed of several muscles. A muscle may participate in more than one sling, and the slings may overlap and interconnect, depending on the task in hand. There are several slings of myofascial systems in the outer unit, including (but probably not limited to) a *coronal* sling (having medial and lateral components), a *sagittal* sling (having anterior and posterior components), and an *oblique spiral* sling. The hypothesis is that the slings have no beginning or end, but rather connect as necessary to assist in the transference of forces. It is possible that the slings are all part of one interconnected myofascial system, and a sling that is identified during any particular motion could merely be a result of the activation of selective parts of the whole sling (Lee 2004).

The identification and treatment of a specific muscle dysfunction (such as weakness, inappropriate recruitment, or tightness) is important when restoring force closure (second component of stability) and for understanding why parts of a sling may be restricted in motion or lacking in support. Note the following points:

- The four systems of the *outer core unit* are dependent upon the *inner core unit* for the joint stiffness and stability necessary for creating an effective force generation platform.

- Failure of the inner unit to work in the presence of outer unit demand often results in muscle imbalance, joint injury, and poor performance.

- The outer unit cannot be effectively conditioned by the use of modern resistance machines, as the specific training provided by these types of machine generally does not relate to day-to-day functional movements.

- Effective conditioning of the outer unit should include exercises that require integrated function of the inner and outer units, using movement patterns common to any given client's work or sport environment (Chek 1999).

In Chapter 4 I will discuss the walking cycle (gait cycle); if you have a good understanding of the information regarding the myofascial sling systems, then, hopefully, it should make perfect sense how these slings are now incorporated into this cycle. I truly hope that as you read that particular chapter, the pieces of the jigsaw puzzle will slowly begin to form a recognizable picture. My goal is for you to come back to each specific chapter time and time again, to try to understand and digest what I have written. More importantly, however, I want you to be able to use this information in your own clinical setting to assess and treat your own athletes and patients.

Exercising the Outer Core

I personally believe that when most people go to the gym to exercise, they generally perform routines that are typically frontal-plane or sagittal-plane types of exercise: they either lift a weight to the sides (frontal plane) of their body or to the front (sagittal plane). If one were to ask these individuals to demonstrate an exercise to train their *core*, and also to perform that specific exercise in the transverse plane, I am sure that after some thought they would probably lie on their back and perform an abdominal crunch type of motion with a rotation; in other words, their elbow would be directed toward their opposite knee while performing the crunch movement, as shown in Figure 3.16(a).

Figure 3.16. (a) Abdominal crunch in the transverse plane.

Let's be a little realistic here. Apart from when we get out of bed in the morning, when do we ever perform that type of motion on a daily basis? When do we lie on our back and rotate the elbow toward the opposite knee? I would call this exercise *non-functional*, even though the majority of gym users routinely perform this exercise for their core muscles every day in their personal exercise routines.

If you think about it, most sporting movements, or simply walking come to that, normally involve some type of action in the *transverse plane* (movement across the body) of motion. Does it not make perfect sense, therefore, to train specifically within the parameters of the transverse plane, in combination with training in the sagittal (coronal) and frontal planes?

Movement-Based Exercise

The inner core unit musculature is generally made up of postural (tonic) muscle types that function mainly as stabilizers. These inner core muscles effectively stabilize the spine and SIJ at low levels of muscular contraction, with a low susceptibility to fatigue. Coordination of the inner core is critical for proper stabilization, which then allows a coordinated recruitment of the muscles of the outer core unit. The ability of the inner core unit muscles to contract prior to force production by the phasic muscles (biased toward movements) is actually considered more important than their inherent strength.

The outer core unit is mainly a phasic system, with large muscles that have the ability, because of the fact that they are very well orientated, to produce enough force to subsequently propel the body forward. The outer core, consisting of the four myofascial slings, also plays a very important role in stabilization of the pelvis, as all of the four individual slings mentioned earlier cross this area and naturally assist in force closure of the SIJ.

With regard to functional types of exercise, movement patterns must be identified and resistance applied to those patterns in a specific way. This is what resistance training is all about … resisting movements!

If specific movements performed by athletes and patients on a daily basis can be identified, these can be replicated by using some form of resistance training, thereby creating a stability protocol. This stability protocol will be further enhanced if these movements can be performed at a speed of contraction that mimics their daily functions. This will not only improve levels of overall fitness but also promote force closure of the pelvis, and subsequently promote a stable foundation. Each exercise will now have a direct purpose and function, instead of just increasing the size of the cross-sectional area of a particular muscle.

Before embarking on a training program for the outer and inner core, it is important to understand the meanings of the words "rep" and "set."

Repetitions and Sets

Definition: A *repetition* (or *rep*) is one complete motion of an exercise. A *set* is a group of consecutive repetitions.

You may have heard someone comment that they performed, for example, three sets of 12 reps on the bench press machine. This means that they did 12 consecutive bench presses, had a break (rest), and then repeated the process a further two times.

There is no simple answer to the question of how many repetitions and sets should be performed, as the number of repetitions required depends on many factors, including where the patient/athlete is in their current training and what their individual goals are. Remember, the purpose of this book/chapter is to improve the optimum functionality of the pelvis through activation of the outer core unit so that your patient/athlete can perform the activities needed for everyday life, as well as participate in any sports-related activities. I suggest we aim for between 10 and 12 reps and between one and two sets of each exercise, at least to start with.

Please also remember that, as with any training program, the workouts will need to be progressive. For example, let's say the patient/athlete starts with two or three exercises that I have chosen from the above primary movement patterns, and they perform two sets of 10 reps for each exercise; when the patient gets to the stage where they find these exercises to be relatively easy, it is then time to progress. This might happen after one week or it might take longer, perhaps three or four weeks. The exercise can be made more difficult by simply changing the number of repetitions, reducing the rest period between sets, adding in another exercise, or changing the resistance of the band (another color), as shown in Figure 3.16(b). For example, the green band is level 1 (easy), the blue band is level 2 (moderate), and the black band is level 3 (hard).

Figure 3.16. (b) Color of band indicates the level of resistance.

To progress in the program, you could, for example, ask the patient to either increase the number of repetitions, i.e. perform two sets of 12 reps (instead of 10 reps), or rest for only 30 seconds (instead of 45 seconds) between the sets. I highly recommend that everything be written down, as it is very easy to forget what was done in the previous training session—trust me on this! I can guarantee that within a few weeks the patient/athlete will easily be doing three sets of 12–15 reps for six or seven different types of outer core exercise.

The following exercises do not specify the number of repetitions and sets next to the exercise diagram, as I want to demonstrate how to perform the individual exercises correctly. Refer to Appendix 2 at the end of the book for an "Exercise Stabilization Sheet" for the outer core muscles; it has been designed specifically for you to photocopy and give out to your athletes and patients (or even for your own personal use). The blank boxes allow you to record the number of repetitions and sets for your patient's rehabilitation program for the pelvis.

Unfortunately, there are a multitude (indeed, an almost infinite number) of movements that are performed in everyday life, making it near impossible to ensure that they are all included in every gym-based training program. However, I have selected the following six exercises, which can be incorporated into any strength and stability training regime, as they will specifically target the global muscles of the outer core sling system.

Primary Movement Patterns

The following exercises are what I consider to be the primary movement patterns, and one or more of these demonstrated exercises can be included in any functional, strength, or stability training program. The therapist/trainer should nevertheless be able to modify and adapt these primary movement exercise patterns accordingly (I will explain later in this chapter). This adaptability protocol will make the exercises far more functional, as well as being more interesting and specific to the needs and demands of your athletes and patients.

Some of the exercises I mention will activate one particular sling more than another; remember, however, that there is a natural cross-over on each exercise, so it is difficult to exercise and target only one specific sling at a time. This is because all of the four slings I have mentioned have to be involved in one way or another, depending on the particular movement one is performing. For example, the anterior and posterior oblique sling will be classified as agonist and antagonist (opposite to each other); however, I consider them to be also synergists (helpers to each other), because when you walk or run in a forward direction, the right arm moves in a forward motion, subsequently activating the anterior oblique sling, but at the same time the left arm moves in a backward type of motion, activating the posterior oblique sling. Hence the opposite and synergistic theory!

I believe the theory above is explained very well by the following:

"When walking or running, every forward motion of the right limb elicits an automatic backward motion of the left limb, and vice versa. You cannot have one movement without the other."

The six primary movement pattern exercises are:

1. Push
2. Pull
3. Squat—Bend to Extend
4. Bend to Extend with Rotation
5. Single-Leg Stance
6. Rotation

Each of these movement patterns can be reproduced in a gym environment using specific exercise machines (e.g. cable machine) or resistance bands; they can, however, also be performed practically anywhere, as the majority of the exercises that I demonstrate in this chapter simply involve using a single piece of resistance exercise band, a core ball, and some dumbbells. Example movement/exercises for incorporating sling patterns are presented in the following sections.

Figure 3.17. Anterior Oblique Sling: (a) start position; (b) finish position.

1. Push

The first exercise I propose is very effective at utilizing the *anterior oblique* sling. If you look at the start position in Figure 3.17(a), you will notice that the exercise band (alternatively a cable machine can be used) is held with the athlete's right hand at shoulder height, and their left arm and left leg are placed in a forward position. The exercise motion is shown in Figure 3.17(b): the athlete pushes the band forward across their body, using their stance leg adductors, internal oblique, and contralateral external oblique. At the same time, the left arm comes backward, as this induces a rotation of the trunk to the left side, subsequently working the anterior oblique sling in the transverse plane of motion.

All day-to-day movements will work this muscle sling, but particularly good examples are the actions of walking, running, and throwing.

> **Note:** It is very important that the athlete control the motion in both phases, i.e. the concentric (shortening) phase and the eccentric (lengthening) phase, and not let the band control the movement. Moreover, one has to be very aware of the activation of the inner core musculature in order to provide the necessary stability to perform all of these exercises I describe. If you are unsure about performing these exercises, please seek professional advice before you begin any type of resistance training.

I always say the following to my athletes and patients during the demonstrations, as I consider it to be relevant to all of the sling exercises:

"You control the movement—don't let the movement control you."

2. Pull

This particular exercise is one of my personal favorites, as it is very effective in utilizing the *posterior oblique* sling. If you look at the start position in Figure 3.18(a), you will see that the exercise band/cable is held with the athlete's right hand at shoulder height, and their left leg and left arm are placed in a backward position. The exercise motion is shown in Figure 3.18(b): using the latissimus dorsi, thoracolumbar fascia, and contralateral Gmax, the athlete pulls the band backward across their body with their right arm. At the same time, the left arm comes forward, as this induces a rotation of the trunk to the right side, subsequently working the posterior oblique sling in the transverse plane of motion.

I often say the following when teaching a class, or even to my athletes and patients, as it I consider it reinforces perfectly the motion in the two exercises outlined above:

"Every pull is a push and every push is a pull—you cannot have one without the other."

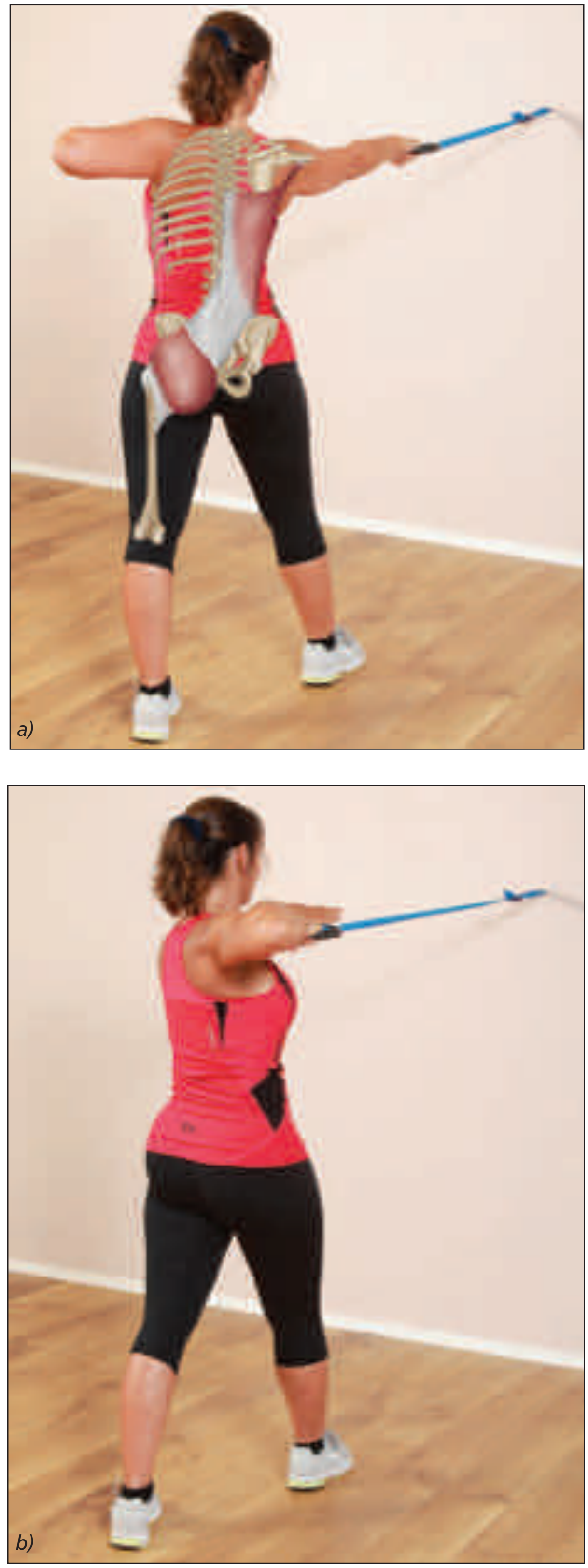


Figure 3.18. Posterior Oblique Sling: (a) start position; (b) finish position.

3. Squat—Bend to Extend

Any exercise or motion that incorporates a bend-to-extend type of motion, such as a typical squat or a dead lift, will incorporate the *posterior (deep) longitudinal sling* as well as involving the *posterior oblique sling*.

Core Ball Squat

A core ball is placed against the wall, and the patient positions themselves so that the core ball is located near their lower back, as shown in Figure 3.19(a). From this position, the patient steps forward slightly, with their knees shoulder-width apart. The patient is then asked to activate the inner core and slowly squat (eccentric phase) until they reach a position of approximately 90 degrees, as shown in Figure 3.19(b). The therapist makes sure that the tracking of the patella is toward the patient's second toe and that the patella does not pass beyond the level of the toes, as indicated by the arrows in Figure 3.19(b). The patient is then instructed to stand up on the return (concentric phase) for a count of two; they are also instructed to squeeze their glutes just before the end phase of the squat.

Figure 3.19. Core Ball Squat: (a) start position; (b) full-squat position.

Progression 1: With Weight

The Core Ball Squat exercise is performed as explained above, except the patient now holds a light weight in each hand, as shown in the start position in Figure 3.20(a). The concentric phase of the squat is shown in Figure 3.20(b).

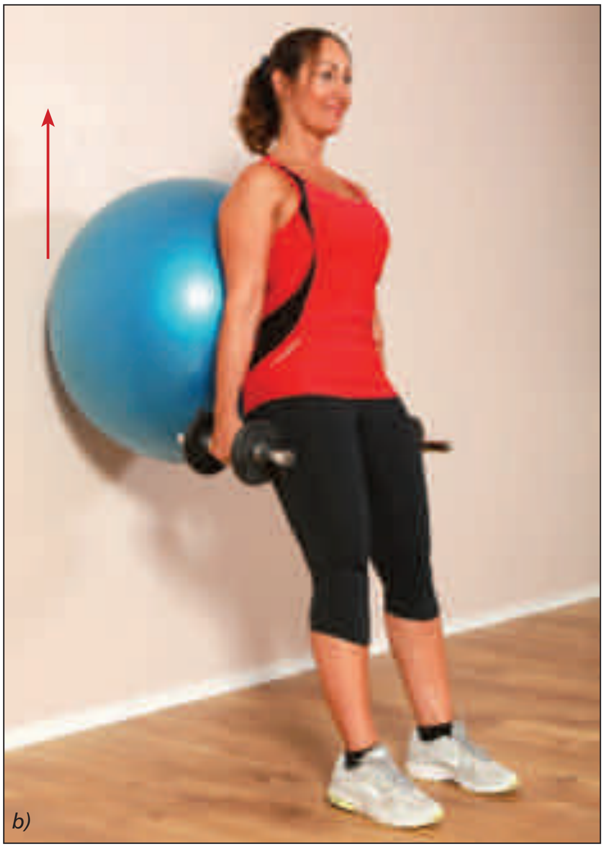


Figure 3.20. Core Ball Squat with Weight: (a) start position; (b) concentric phase.

Progression 2: With Weight and Without a Core Ball

The start position of this progression is shown in Figure 3.21(a): the athlete holds a dumbbell in each hand, with their knees shoulder-width apart. The squat is then performed to reach a knee-bend of approximately 90 degrees, as shown in Figure 3.21(b).

Please remember that the patella follows an imaginary line to the second toe and does not pass the level of the toes. From the 90-degree position, the athlete then rises to return to the start position. (This exercise can be performed with or without dumbbells.)

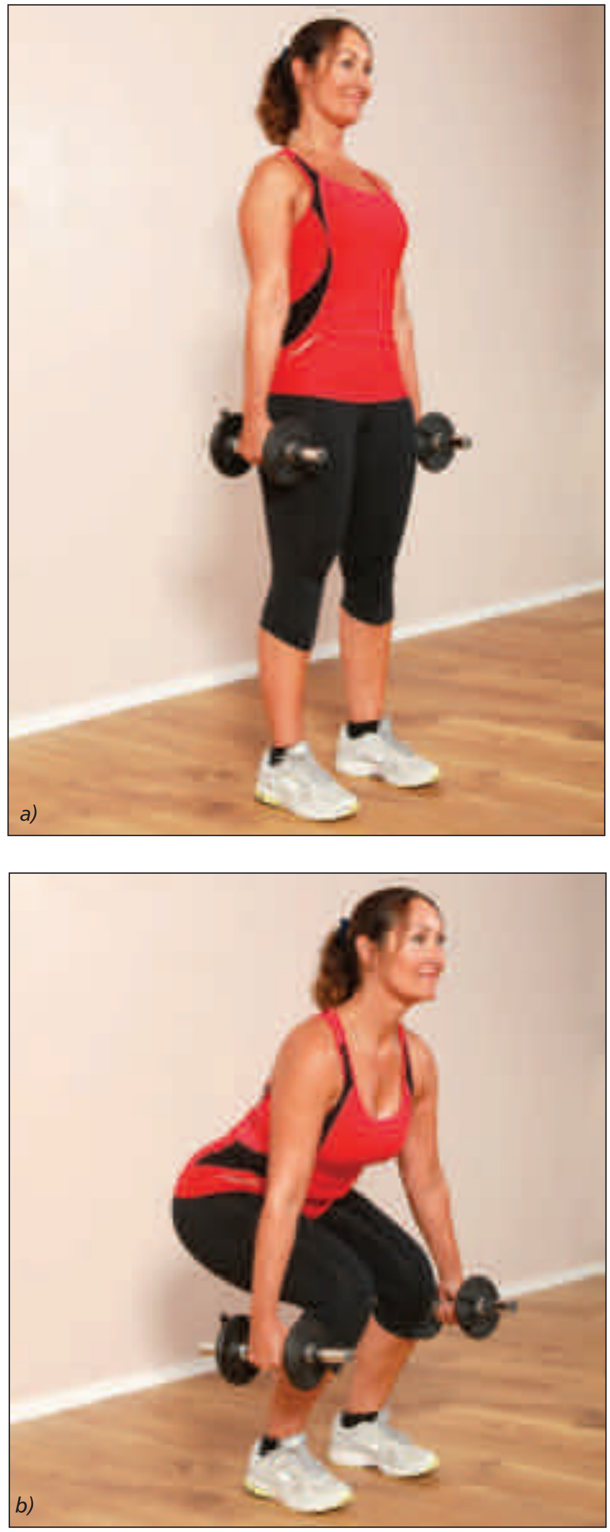


Figure 3.21. Squat with Weight: (a) start position; (b) finish position.

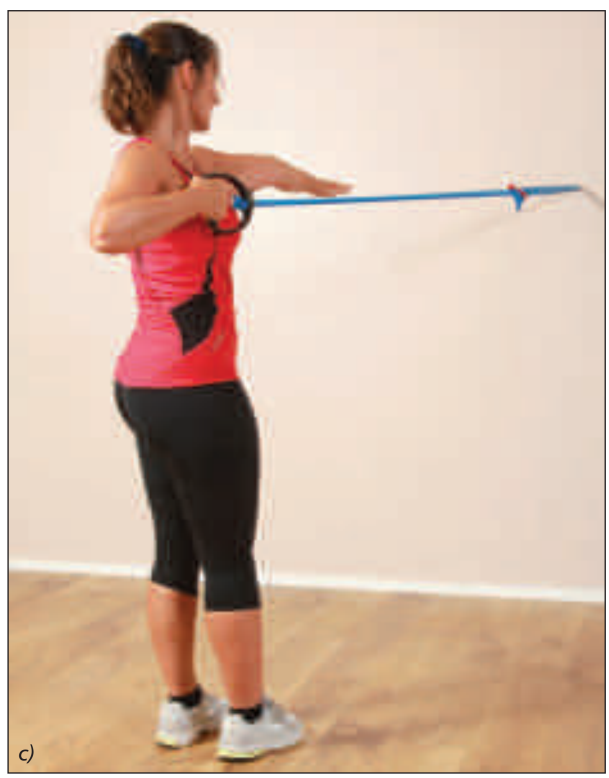
4. Bend to Extend with Rotation

A bend-to-extend type of movement with a rotation is an excellent way of incorporating the *posterior (deep) longitudinal sling* as well as the *posterior oblique sling*, all at the same time. In the start position shown in Figure 3.22(a), the athlete's right hand holds the exercise band/cable at shoulder height in a forward position, and their left arm is placed in a backward position. Notice that the athlete has adopted a type of squat position, which can vary in terms of depth; the athlete here has adopted an angle of 45 degrees, but one can choose to start at a smaller or greater angle, depending on requirements.

The exercise motion is shown in Figure 3.22(b): the athlete pulls the band backward across their body, using both of their posterior slings. At the same time, the left arm comes forward as the athlete returns to the erect position. Figure 3.22(c) shows an alternative end position for the right arm, as some patients find this movement easier. What I sometimes suggest is that my athletes vary or alternate the two movements described above.

a)

b)



c)

Figure 3.22. Posterior (deep) Longitudinal and Posterior Oblique Sling: (a) start position; (b) finish position; (c) alternative position for the arm at the end of motion.

5. Single-Leg Stance

The *lateral sling* system helps to stabilize the body in the frontal plane. During any type of single-leg stance the hip abductors—gluteus medius (Gmed) and gluteus minimus (Gmin)—and the adductors of the supporting leg work in conjunction with the contralateral (opposite) quadratus lumborum (QL) to stabilize the pelvis. The internal and external oblique abdominal musculature also works synergistically to secure a stable spine and pelvis. Dysfunction of the lateral sling system is a common source of injury to the back, the SIJ, and also the supporting leg. If you think about it, most sports are single-leg dominant in nature. During walking, but especially running and sprinting, the body is propelled forward through powerful single-leg actions, so the need for a strong and functional lateral sling system is of paramount importance. This specific sling system will help improve overall athletic performance and conserve energy expenditure, as well as reducing the possibility of sustaining musculoskeletal types of injury.

Any exercises which incorporate a movement that relies on being in a single-leg stance position will activate the muscles of the lateral sling. The last chapter of *The Vital Glutes: Connecting the Gait Cycle to Pain and Dysfunction* (Gibbons 2014) specifically targets exercises that are biased toward a single-leg stance position in order to activate the Gmed muscle in particular of the lateral sling system. For this text I will therefore include an exercise that is demonstrated on one leg; however, I am also going to simultaneously target the anterior and oblique slings while performing a push and a pull motion as described earlier.

> **Note:** If you have difficulty standing on one leg, possibly because of weakness of the lateral sling, I recommend that you read the vital glutes book (Gibbons 2014) first, so that you will have a better understanding of why and how to initiate the strengthening of the Gmed/lateral sling system before embarking on trying to perform the following exercise.

Lateral Sling and Anterior Oblique Sling

Figure 3.23(a) shows the athlete in a single-leg stance position (lateral sling), while at the same time holding the exercise band with their right hand, with the arm raised to 90 degrees; the left arm is held in a forward position and the body is rotated to the right. The athlete then pushes the right arm forward while the left arm moves backward; this will induce a rotation of the trunk to the left side, as shown in Figure 3.23(b), subsequently activating the anterior oblique system and at the same time utilizing the lateral sling musculature.

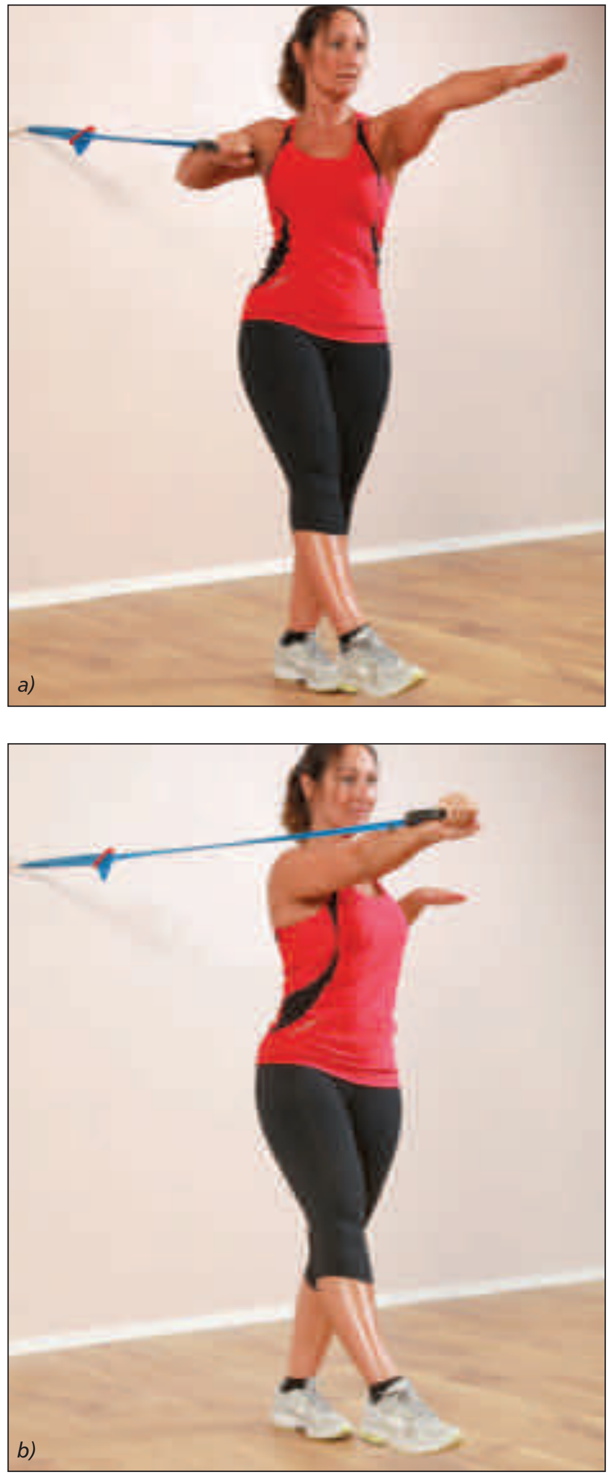
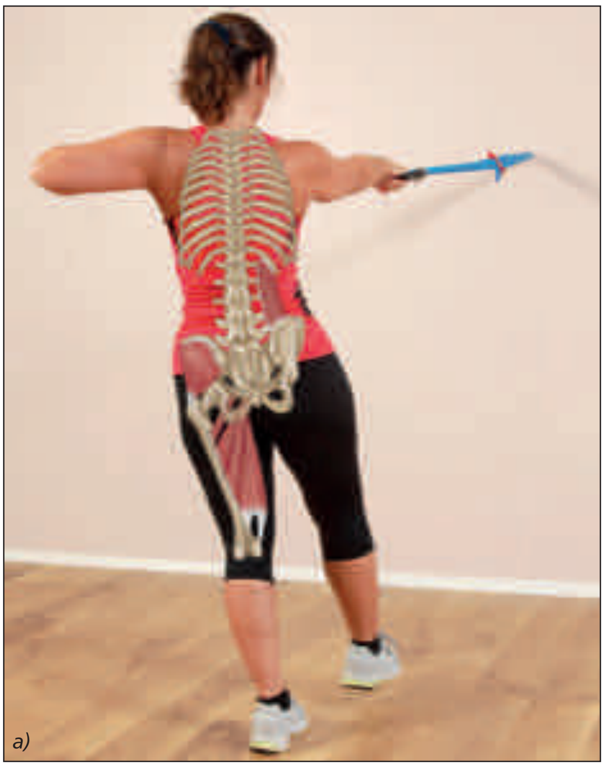


Figure 3.23. Lateral Sling and Anterior Oblique Sling: (a) start position; (b) finish position.

Lateral Sling and Posterior Oblique Sling

Figure 3.24(a) shows the athlete standing on one leg (lateral sling), while at the same time holding the exercise band with their right hand, with the arm raised to 90 degrees; the left arm is held in a backward position and the body is rotated to the left. The athlete then pulls the right arm backward while the left arm moves forward; this will induce a rotation of the trunk to the right side, as shown in Figure 3.24(b), causing an activation of the posterior oblique system and at the same time utilizing the lateral sling muscles.


a)


b)

Figure 3.24. Lateral Sling and Posterior Oblique Sling: (a) start position; (b) finish position.

6. Rotation

The last motion of the primary movement patterns is *rotation,* which will utilize mainly the internal and external obliques as well as the gluteal muscles.

Anterior Rotation

Figure 3.25(a) shows the athlete standing with their legs shoulder-width apart, holding the exercise band with their right hand, and stabilizing the inner core muscles. The athlete rotates their body to the left, which will utilize the oblique muscles, as shown in Figure 3.25(b). The arm should be relatively fixed, since the motion is from the trunk and not from the movement of the arm.

Figure 3.25. Oblique Sling—Anterior Rotation: (a) start position; (b) finish position.

Posterior Rotation

Figure 3.26(a) shows the athlete standing with their legs shoulder-width apart, holding the exercise band with their left hand, and stabilizing the inner core muscles. The athlete rotates their body to the left, which will utilize the oblique muscles, as shown in Figure 3.26(b). The arm should be relatively fixed, since the motion is from the trunk and not from the movement of the arm.

Figure 3.26. Oblique Sling—Posterior Rotation: (a) start position; (b) finish position.

Exercise Variations

I have demonstrated and explained six primary movement patterns that can be included in an outer core stabilization program. When I see athletes and patients for the first time I normally suggest that only two initial exercises are performed to start with, namely a *pull* motion and a *push* motion. I recommend that they do between 10 and 12 reps on both sides (push exercise on the left and push on the right, then the same for the pull exercise) and repeat for two/three sets (10–12 × 2/3). I suggest starting with 10 reps initially, for one or two sets (once per day), and progress to 15 reps for three sets per day over a couple of weeks.

When patients visit me for their second and third sessions, I will personally check their technique before I give them another exercise; this way I can make sure that what I showed them initially is being reiterated in their demonstration back to me. When I am happy with what they have shown me, then, and only then, will I give them another one (or possibly two) of the primary movement exercises listed above.

Once all of the six exercises have been incorporated into their exercise regime, we can then start to add a bit of variety and adapt the exercises accordingly to make them more specific and tailored to the athlete, depending on their individual sporting requirements. Although the following exercises are explained and demonstrated for only one side of the body, they would of course be incorporated in a program for both sides (an exercise performed on the right is repeated on the left, and so on).

Combined Push–Pull

The athlete in Figure 3.27(a) holds a piece of exercise band with their left hand and another piece of exercise band with their right hand. They are asked to combine the motion of a push from the right arm and a pull from the left arm, as indicated in Figure 3.27(b). It is recommended that the inner core muscles are activated, to make sure that they are stable while performing this motion.

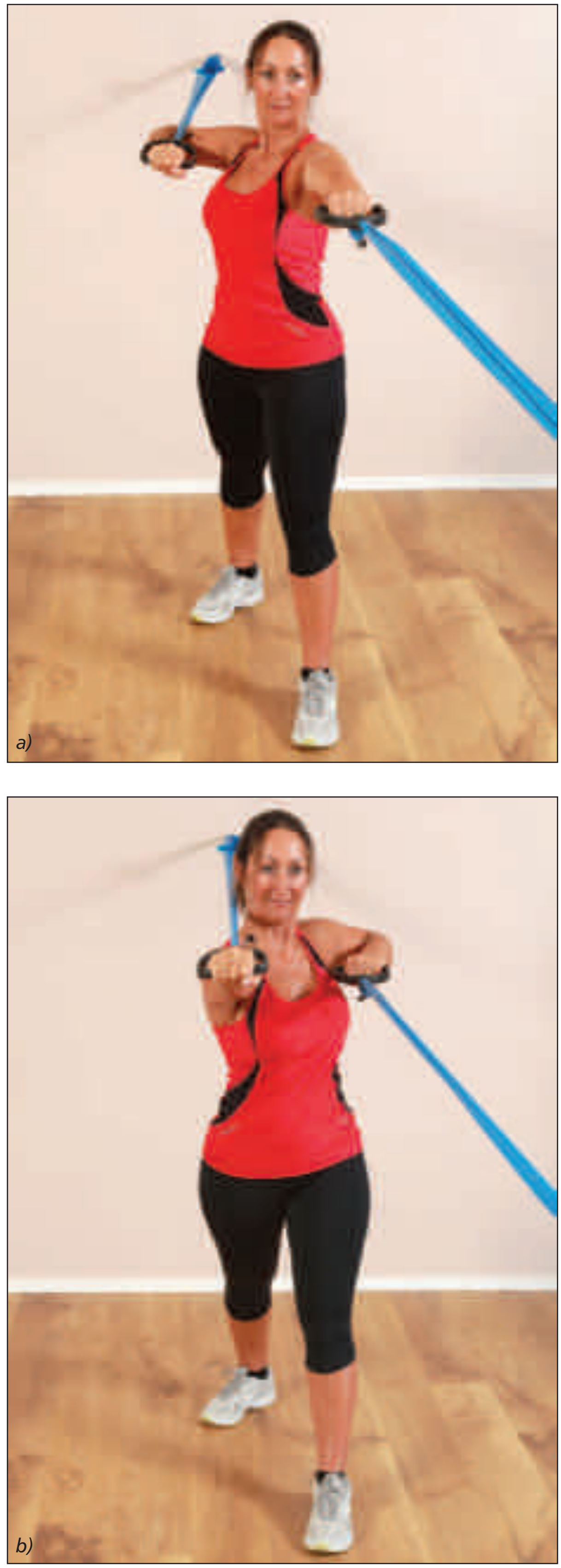


Figure 3.27. Combined Push–Pull: (a) start position; (b) finish position.

Combined Push–Pull on One Leg

This is the same exercise as above, but this time the athlete adopts a single-leg stance position while grasping the exercise bands, as shown in Figure 3.28(a). The motion is a combination of a push from the right arm and a pull from the left arm while standing on one leg, as indicated in Figure 3.28(b).

Figure 3.28. Combined Push–Pull on One Leg: (a) start position; (b) finish position.

Push with Lunge

In the start position shown in Figure 3.29(a), the athlete is holding the exercise band with the right hand at shoulder height, and the left arm and left leg are placed in a forward position. The exercise motion is shown in Figure 3.29(b): the athlete pushes the band forward across their body, while at the same time the left arm moves backward as the left knee bends to perform a lunge type of motion. (Note: the left knee does not past the level of the toes, and the patella follows the second toe.)


a)


b)

Figure 3.29. Push with Lunge: (a) start position; (b) finish position.

Pull with Lunge

In the start position shown in Figure 3.30(a) you will notice that this time the athlete is holding the exercise band with their right hand placed in a forward position at shoulder height; the left arm is held in a backward position, with the left leg forward. The exercise motion is shown in Figure 3.30(b): the athlete pulls the band backward across their body, while at the same time the left arm moves forward as the right knee bends to perform a lunge type of motion. (Note: the right knee does not pass the level of the toes, and the patella follows the second toe.)

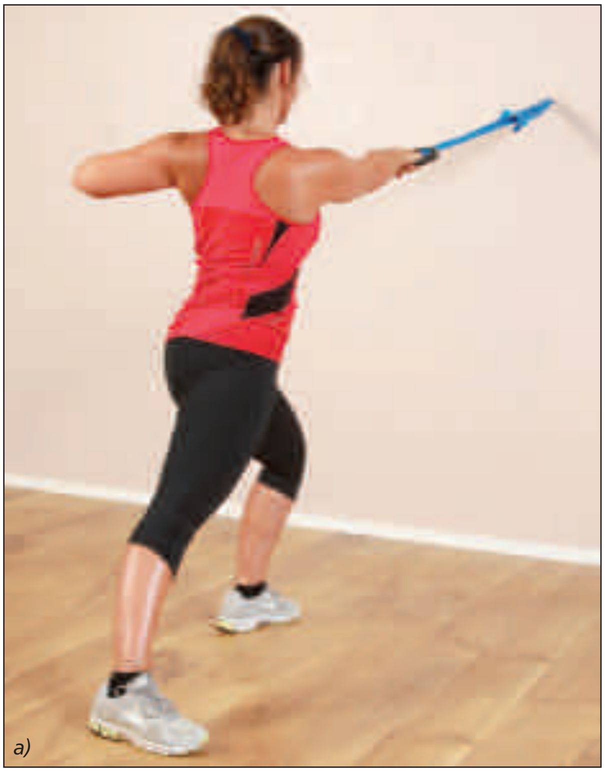


Figure 3.30. Pull with Lunge: (a) start position; (b) finish position.

Push on Unstable Base

In the start position shown in Figure 3.31(a), the exercise band is held in the right hand at shoulder height, and the left arm is placed in a forward position. Overleaf, the exercise motion is shown in Figure 3.31(b): the athlete pushes the band forward across their body, and at the same time the left arm moves backward while maintaining stability on the unstable base.

Figure 3.31. Push on Unstable Base: (a) start position.

Figure 3.31. Push on Unstable Base: (b) finish position.

Pull on Unstable Base

In the start position shown in Figure 3.32(a), the athlete holds the exercise band in the right hand at shoulder height, and the left arm is placed in a backward position. The exercise motion is shown in Figure 3.32(b): the athlete pulls the band backward across their body, and at the same time the left arm moves forward while maintaining stability on the unstable base.

Figure 3.32. Pull on Unstable Base: (a) start position; (b) finish position.

Bend to Extend with Rotation on Unstable Base

In the start position shown in Figure 3.33(a), the athlete holds the exercise band with their right hand at shoulder height and places their left arm in a backward position, while adopting a squat position on the unstable base. The exercise motion is shown in Figure 3.33(b): the athlete pulls the band backward across their body, and at the same time the left arm moves forward as they return to the erect position while maintaining stability on the unstable base.


a)


b)

Figure 3.33. Bend to Extend with Rotation on Unstable Base: (a) start position; (b) finish position.

Bend High to Low (Wood Chop)

In the start position shown in Figure 3.34(a), the athlete holds the band simultaneously with their right and left hands at a point above shoulder height. The exercise motion is shown in Figure 3.34(b): the athlete pulls the band across their body to a low position, while at the same time performing a squatting motion. This movement is similar to chopping wood.

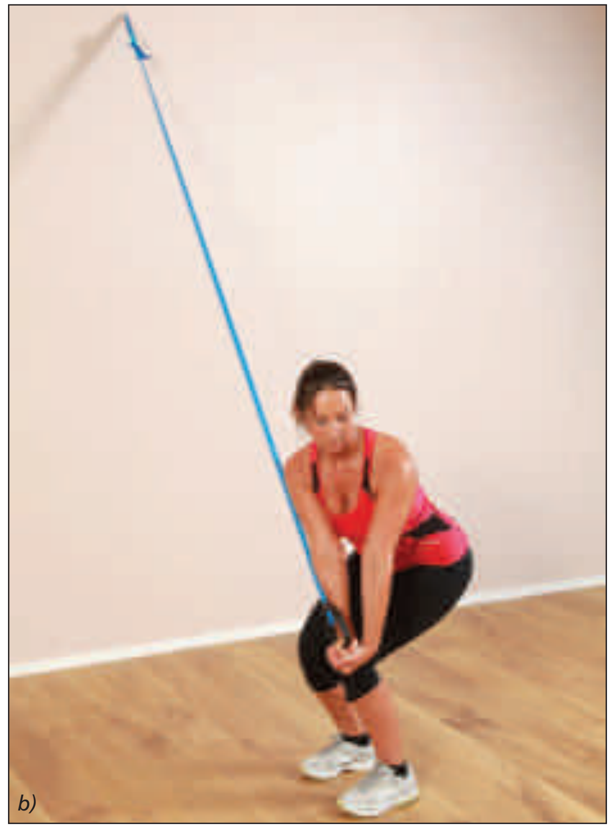


Figure 3.34. Bend High to Low: (a) start position; (b) finish position.

Bend Low to High (Reverse Wood Chop)

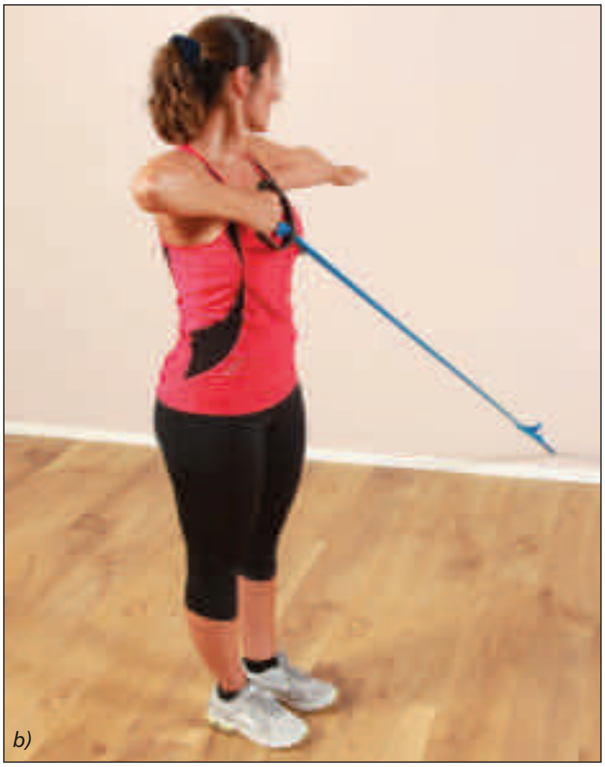
In the start position shown in Figure 3.35(a), the athlete squats down and holds the band simultaneously in the right and left hands at a point below shoulder height. The exercise motion is shown in Figure 3.35(b): the athlete pulls the band across their body to a high position, while at the same time rising from the squat to an erect position.

Figure 3.35. Bend Low to High: (a) start position; (b) finish position.

Bend Low to High (Single Arm)

A combination of a bend-low-to-high type of movement with a rotation and a squat is an excellent way of incorporating the posterior longitudinal sling as well as the posterior oblique sling, both at the same time. In the start position shown in Figure 3.36(a), you will see that the athlete is holding the exercise band/cable at a lower level with their right hand in a forward position, and the left arm is placed in a backward position; the trunk adopts a position of left rotation. The athlete has also adopted a squat position, which can vary in terms of depth: here the athlete has squatted to an angle of 45 degrees, but this angle can be smaller or greater, depending on requirements. Overleaf the exercise motion is shown in Figure 3.36(b): the athlete pulls the band backward and high across their body, using both of their posterior slings. At the same time, the left arm comes forward while the trunk rotates to the right as the athlete returns to the erect position.

Figure 3.36. Bend Low to High (Single Arm): (a) start position.



b)

Figure 3.36. Bend Low to High (Single Arm): (b) finish position.

Oblique Sling—Anterior Rotation on Unstable Base

In this demonstration shown in Figure 3.37(a), the athlete starts with their legs shoulder-width apart, and holds the exercise band with their right hand while stabilizing their inner core muscles. The athlete then rotates their body to the left, while maintaining stability on the unstable base, as shown in Figure 3.37(b). The arm should be relatively fixed, since the motion is from the trunk and not from the movement of the arm (the same exercise can be repeated for a posterior rotation; see Oblique Sling—Posterior Rotation).

a)

b)

Figure 3.37. Oblique Sling—Anterior Rotation on Unstable Base: (a) start position; (b) finish position.

Oblique Sling—Anterior Rotation on One Leg

Figure 3.38(a) shows the athlete standing with their legs shoulder-width apart and holding the exercise band with their right hand, while stabilizing the inner core muscles. The athlete then rotates their body to the left while performing the exercise in a single-leg stance position, as shown in Figure 3.38(b). The arm should be relatively fixed, since the motion is from the trunk and not from the movement of the arm (the same exercise can be repeated for a posterior rotation; see Oblique Sling—Posterior Rotation).


a)


b)

Figure 3.38. Oblique Sling—Anterior Rotation on One Leg: (a) start position; (b) finish position.

Rotation While Kneeling

For an anterior rotation, the athlete in Figure 3.39(a) kneels on an exercise mat, with their knees shoulder-width apart, and holds the exercise band with their left hand while stabilizing the inner core muscles. The athlete then rotates their body to the right while performing the exercise in a kneeling position, as shown in Figure 3.39(b). The arm should be relatively fixed, since the motion is from the trunk and not from the movement of the arm.

Figure 3.39. Oblique Sling—Anterior Rotation While Kneeling: (a) start position; finish position.

The same exercise can be repeated for a posterior rotation, as shown in Figure 3.40.

Figure 3.40. Oblique Sling—Posterior Rotation While Kneeling: (a) start position; (b) finish position.

Conclusion

We need the inner and outer core units to function synergistically to: (1) stabilize the body; and (2) create powerful and economic movement. Without efficient functioning of the inner unit there is no stability of the spine and SIJs. Moreover, the core will not be able to provide a stable base of contraction for the phasic muscles (outer core) to contract, which can result in a loss of limb power and a reduced economy of movement patterns, as well as an increased susceptibility to musculoskeletal injuries.

A well-conditioned inner core unit is very dependent on strong outer core unit systems, and vice versa, in order to protect the smaller inner unit muscles, the spinal ligaments, and the associated joints of the spine and pelvis.

Let me try to explain this concept with the following example. I have been fortunate to work with the Oxford University Boat Team for many years. When they have been rowing on very flat and calm lakes and rivers, I have mentioned to them many times (mainly during training sessions) that the outer core unit (i.e. the phasic muscles) is doing most of the work to propel the boat through the water, and the inner core unit is relatively relaxed (by comparison), especially on calm water.

I am currently the sports osteopath for the team, so when they finish rowing I always ask them how they feel (in terms of their lower back and pelvis, etc.); I can honestly say that most of the time there are no reports of musculoskeletal issues. However, when the team row on the "tideway" (the River Thames in London) in preparation for the annual Boat Race, it is a completely different story; this river can be very unpredictable—one minute the river is particularly choppy and the next it is calm. The River Thames is tidal fed from the sea, which alters the tone of the water; in addition, passing motorboats produce waves that can also affect the flow and manner of the water. Because of these variable circumstances, if the river appears rougher than usual, then I consider the inner core unit to be working a lot harder than normal, because it has to stabilize each of the individual rowers in their seats. Moreover, the inner core unit is trying to stabilize the rowing boat to prevent it from tilting from side to side, while at the same time the outer core unit is still being utilized to propel the boat forward. At the end of the training session, I ask the rowers the same question (relating to any issues with the lower back); in this case, probably around half of them say that they need to see me for treatment to help reduce the symptoms that they are experiencing.

In order to have a strong outer core unit, it is paramount that the inner core unit be stabilized first, as the most susceptible area in a rower's musculoskeletal system is the lower lumbar spine—usually disk injuries occur to L4/5 (4th and 5th lumbar vertebrae) or to L5/S1 (5th lumbar vertebra/1st sacral vertebra).

Most of the rowers know a bit about core stability training, and some have done one or two exercises before, mainly abdominal trunk curls and planks (two exercises that I typically classify as *non-functional* and definitely not effective for the inner core—hence not recommended). During the times I have been involved in their training, I have tried to make the inner core training fun, as these exercises are generally not appealing to a bunch of fit young rowers who are used to doing only bench presses, squats, and lunges.

For example, I would get all the team (eight in this case, or nine including the cox) to sit on gym balls in a straight line, one behind the other, facing the same way—except for the cox at the end, who would sit facing them. While sitting on the ball, they would then place their feet on the ball in front and try to maintain stability by using their inner core muscles, which is especially challenging, as the feet are now lifted off the floor.

The idea of this exercise was to mimic sitting in a boat on water. From this position, each team member had to keep the line of eight rowers (nine including cox) stable by activating their inner core muscles. Once this had been achieved, we would then try to mimic the motion of rowing while still sitting on the gym balls. Apart from being fun, this is a great way of activating the inner core muscles without having to think about the processes involved.

This exercise is just one example that emphasizes to the team *why* training the inner core unit is every bit as important as training the outer core unit. The mentality of many athletes who I have come into contact with is to train only the muscles they can see and not the ones that they cannot.

Note: I haven't included many inner core exercise explanations/demonstrations, as I feel it is not within the scope of this book. The reason for this is mainly that I wanted to focus my attention on training and stabilizing the outer core muscles in this text, because I feel that this particular area has been neglected in the past. There are numerous books on the shelves that offer specific inner core activation exercises, so may I suggest you consult one of them. I have discussed here only briefly some of the inner core exercises that I incorporate in the rowing training program—my strategy is to train the rowers' inner core muscles, without them actually being aware that they are training them!