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## PELVIS AND SACRAL DYSFUNCTION IN SPORTS AND EXERCISE

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Pelvic injuries and dysfunctions are not always included in discussions of sports injuries. One report<sup>9</sup> regarding runners indicated that hip, pelvis, and thigh injuries accounted for 5% of all athletic injuries. Distinguishing how many of these involve only the pelvis is impossible. The general term pelvic injury has a wide variety of meanings. Healthcare providers often interpret this term based on their specialty background. The general musculoskeletal practitioner often will focus attention to bony, ligamentous, joint, and muscle injury. Considerable overlap exists regarding referral of pain to the pelvic region from the spine, hip, and lower extremity. Likewise, the pelvis holds important visceral structures that are gender-specific and are supported by the muscular complex comprising the pelvic floor. Trauma or overuse injuries to remote sites can cause adaptive changes in the pelvic floor, which can produce pain and bowel and bladder dysfunction.

In the past, sports medicine literature has often omitted discussions of pelvic injuries related to the pelvic floor. This omission is likely related to a lack of research related to exercise and sports injuries specific to the pelvis. An overlap of problems involving the lumbar spine, hip, and pelvis exists as well. As a result, the healthcare provider needs to pull information from various sources including primary care, orthopedics, urology, physical medicine and rehabilitation, and obstetrics and gynecology. The female pelvis acquires changes with aging. These occur as a result of hormonal changes, pregnancy, childbirth, and menopause. To provide comprehensive management of pelvic and hip problems in women, the healthcare provider must take into account these changes and adapt the therapeutic approach accordingly. Ultimately, a better understanding of specific anatomic, physiologic, and biomechanical differences

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between men and women with regard to specific exercise or sport will decrease the number of sidelined female exercisers and athletes.

Overuse injuries are the most common injuries sustained at the pelvis. Treatment should be geared to a holistic approach encompassing bone health, joint function, and muscle activation. The region to be treated goes well beyond the pelvis and must incorporate appropriate mechanics at the lumbar spine and lower extremity.

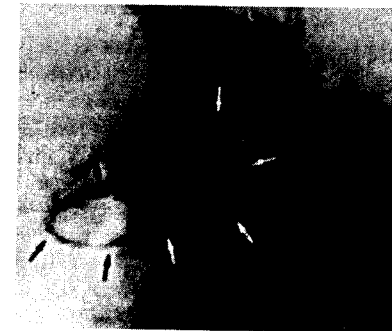
This article focuses on injuries sustained during sports and exercise located primarily at the pelvis. Differences between primary site of injury and adaptive changes are discussed. Pelvic floor pain syndromes and urinary stress incontinence and their effect on the female athlete are reviewed with suggestions regarding specific examination and treatment techniques.

## ANATOMY AND BIOMECHANICS

A good understanding of the anatomy and biomechanics of the hip and pelvis is essential in devising a comprehensive treatment program after an injury. The pelvis serves as the central base through which forces are transmitted both directly and indirectly. The joints of the pelvis are inherently stable joints. Repetitive loads or high-injury loads can lead to ligamentous, bony, and muscle overuse syndromes. Adaptive patterns may occur in the pelvis as a result of spine or lower extremity injuries. Asymmetrical force transmission can then lead to dysfunction at the pelvis. The natural degenerative changes that take place also must be considered in the aging athlete. Women have further physiologic changes during their lifecycle that put them at risk for injury. These changes should be considered during the discussion of mechanics. Further awareness of the physiologic changes that occur during the female lifecycle is important.

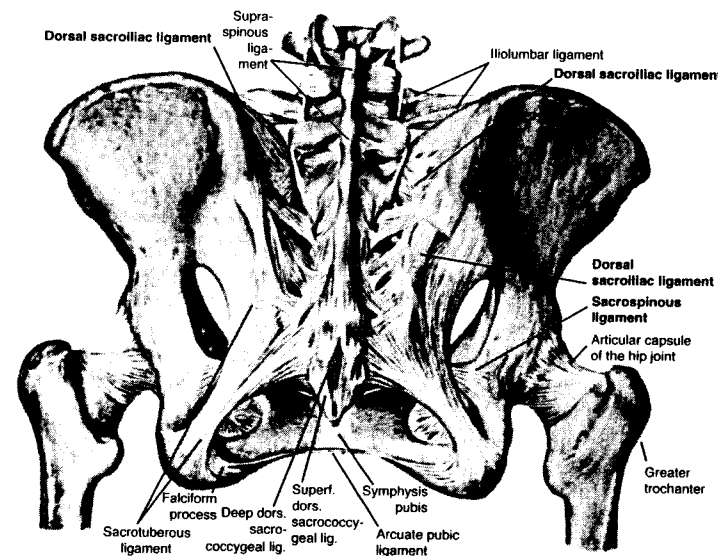
The bony pelvis includes three bones that articulate at three joints. The ilium articulates with the sacrum at the sacroiliac joint. The lumbar spine articulates with the sacrum anteriorly through the lumbar disc and posteriorly through the L5 to S1 facets. The lower extremity extends from the pelvis, including the femur, articulating with the acetabulum at the hip joint. In general, the shape of the bony pelvis of the female is broader than that of the male. The combination of greater femoral neck anteversion and shorter lower extremity limb length leads to a lower center of gravity for women as compared with men.<sup>28</sup> This alignment suggests different adaptive or firing patterns in women versus men but not necessarily increased risk for injury.<sup>8</sup> For both genders, the pelvis is inherently a stable ring. Proper functioning of the joints surrounding the pelvis is key for cohesive mechanics at the pelvis.

The sacroiliac joint (SIJ) meets the definition of a synovial joint, synarthrosis, and amphiarthrosis. The joint is L- or C- shaped with two lever arms that meet at the second sacral level where it interlocks (Fig. 1). The sacral side is lined by thick hyaline cartilage and the ilial side is lined with fibrocartilage. There are intra- and interindividual differences in shape of the joint. The anterior fibrous capsule is well formed, but the posterior capsule is thinner and may have multiple plications. Accessory articulations may occur in up to 35% of the population. These articulations are thought to occur secondary to degenerative changes over time.<sup>4</sup> Ligaments affecting stability of the joint include the intraarticular, periarticular, and accessory ligaments. The interosseous ligaments are the strongest ligaments that support the joint and resist motion between the sacrum and ilium. The thin anterior ligaments pass between the psoas major and the obturator internus and provide a sling for the ilium and sacrum. The posterior



**Figure 1.** Arthrogram of SIJ outlines the "L" or "C" shape of the joint. Arrows indicate capsular margins of joint; L = L5 vertebral segment. (From Cole AJ, Dreyfuss P, Pauza K: Sacroiliac joint injection techniques. In Vleeming A, Mooney V, Dorman T, et al (eds): *The Integrated Function of the Lumbar Spine and Sacroiliac Joint: Part II*. Second Interdisciplinary World Congress on Low Back Pain, San Diego, November, 1995, p 587; with permission.)

ligament has three layers progressing from deep to superficial. The most superficial layer becomes continuous with the sacrotuberous and sacrospinous ligaments. As an accessory ligament, the sacrotuberous ligament influences the joint through load and tension forces from the lower extremity and pelvis (Fig. 2). Laxity or tautness in this ligament influences motion at both the sacrum and ilium. The iliolumbar ligament also affects the joint by preventing anterior



**Figure 2.** The sacrotuberous ligament is an important accessory ligament. The sacrotuberous ligament transmits loads from the lower extremity to the trunk including the SIJ and lumbar spine. (From Greenman PE: *Pelvic girdle dysfunction*. In Greenman PE: *Principles of Manual Medicine*, ed 2. Baltimore, MD, Williams and Wilkins, 1996, p 307; with permission.)

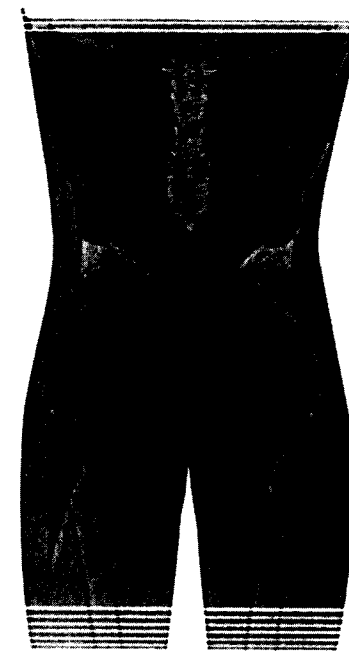
translation and rotation of L5. Vleeming and coworkers<sup>37, 38</sup> best describe the subtle motion changes that occur at the SIJ as a self-locking mechanism. They described stability of the interlocking mechanism as related to form and force closure. Form closure refers to joint surfaces that congruently fit together and require no extra forces to maintain stability. Force closure refers to a joint that requires outside force provided by muscles and ligaments to withstand load. If opposing forces do not have the appropriate form and/or force closure, the joint is less stable and subjected to shear force. In side-to-side comparisons, the shape of the SIJ can vary in individuals; as a result, form and force closure that provide stability may differ as well. In the sports setting, asymmetrical force transmissions can lead to break down or secondary adaptive patterns that facilitate dysfunction or injury.

The form closure in women is less congruent because women have a wider pelvis and decreased joint space surface area as compared with men. Force closure in women is susceptible to hormonal changes that occur during pregnancy. Increased joint laxity occurs, which is related to elevated levels of relaxin and estrogen. These hormones return to baseline in the weeks and months postpartum but less predictably in women who breast feed. Muscle groups that operate at a biomechanical disadvantage during pregnancy and in the postpartum period because of increasing abdominal girth, changes in load transfer, and deconditioning may alter force closure.

The thoracolumbar fascia is important in load transfer from the lower extremity through the pelvis, lumbar spine, and abdominal muscles. The superficial lamina of the thoracolumbar fascia facilitates transmission of forces from the lower extremity to the contralateral latissimus dorsi. These forces cross at the level of the pelvis. This transitional region may be a potential area of breakdown (Fig. 3).<sup>40</sup>

Muscles at the hip, pelvis, and lumbar spine provide indirect motion at the SIJ. Abdominal muscles affect motion at the ilium, pubis, and lumbar spine. The psoas connects the thoracolumbar fascia with the lower extremity and may restrict lumbopelvic rhythm. The hamstring and gluteals directly affect the position of the ilium. They contract to rotate the ilium posteriorly. An inhibited or weak gluteal muscle can facilitate anterior iliac rotation. Hamstrings firing in a shortened position facilitate a posteriorly rotated ilium. Likewise, inhibited hamstrings promote an anteriorly rotated ilium. An anteriorly rotated ilium facilitates the psoas to contract in a shortened position. This furthers the anterior rotation of the ilium and increases lumbar lordosis. The anteriorly rotated ilium also forces the abdominal muscles to fire in an inefficient lengthened position. Muscles functioning in a lengthened position are not able to provide maximal force absorption. Abdominal muscles firing in a lengthened position do not efficiently absorb forces that affect stability at the lumbar spine and pubic symphysis.

Altered lower extremity and pelvic mechanics can then alter pelvic floor function and can lead to secondary pain and potential incontinence in women. In particular, the obturator internus may be susceptible to overload (Fig. 4). This muscle is a primary hip external rotator and abductor. If the gluteus medius is inhibited, the obturator internus is recruited as a hip abductor and may not be strong enough to respond to the load demand or repetition. As a result, an overuse syndrome may develop. Pain in the groin and pelvic floor may be the primary symptom. Other pelvic floor muscles such as the levator ani group must transfer load forces directly and indirectly across the SIJ and pubic symphysis. Although no literature to date describes the pelvic floor biomechanics in relation-

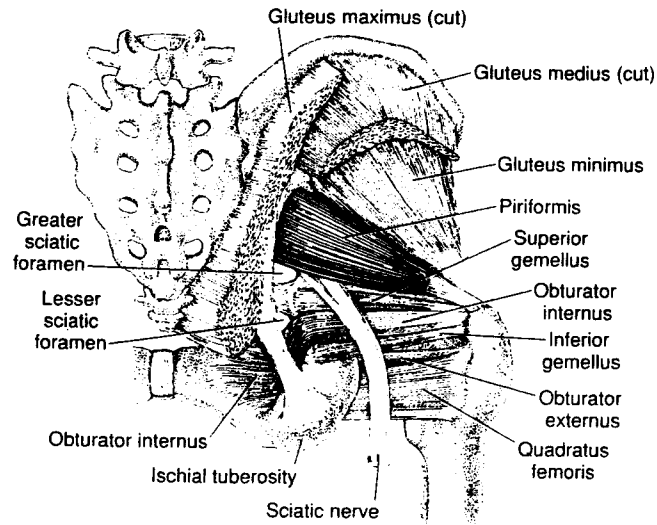


**Figure 3.** Transmission of forces to the contralateral pelvis occurs via the thoracolumbar fascia. (From Cole AJ, Dreyfuss P, Pauza K: Sacroiliac joint injection techniques. In Vleeming A, Mooney V, Dorman T, et al (eds): *The Integrated Function of the Lumbar Spine and Sacroiliac Joint: Part II. Second Interdisciplinary World Congress on Low Back Pain*, San Diego, November, 1995, p 478.)

ship to athletes, the health care provider should be aware of the possibility of dysfunction in athletes with unresolved hip, groin, and pelvic pain.

The innervation of the joint is from multiple root levels of the lumbosacral pelvis. The posterior joint receives innervation from L3 to S3, whereas the anterior joint receives innervation from L2 to S2. The primary innervation is thought to be from the S1 root level.<sup>13</sup> Because of the various levels of innervation, sacroiliac joint pain may present with a variety of pain locations. Similar to its primary level of innervation, SIJ pain often presents with S1 distribution symptoms in the form of pain or numbness.

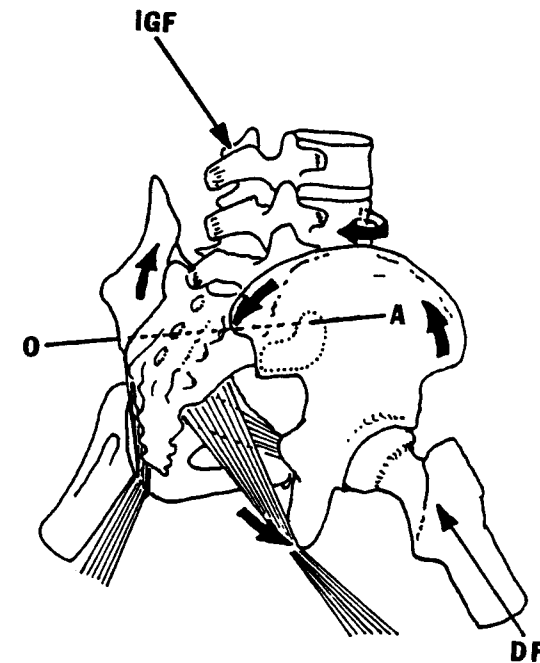
The biomechanics regarding the SIJ are complex (Fig. 5). Most research has looked at one or two components of force and movement. Motion at the SIJ occurs indirectly. Body weight and postural changes may create or inhibit motion at the SIJ. Muscle groups surrounding the joint also cause indirect motion. These groups include gluteals, hamstrings, hip external rotators, psoas, abdominals, latissimus dorsi, quadratus lumborum, and erector spinae. Myofascial changes associated with these muscle groups will alter mechanics. The SIJ forms the base of support for the spine. The joint receives and transmits forces from the trunk and from the lower and upper extremities. Forces absorbed through the SIJ allow changes in body weight transmission to occur while providing stability. SIJ motion is affected by motion at the spine, ilium, pubic symphysis, and hip. Studies have shown various ranges of motion but most agree that approximately



**Figure 4.** The obturator internus muscle primarily activates hip motion. Muscle overuse or inhibition can lead to pelvic floor pain. (From Greenman PE: Exercise principles and prescription. In Greenman PE: Principles of Manual Medicine, ed 2. Baltimore, MD, Williams and Wilkins, 1996, p 466; with permission.)

4° of rotation and 1.6 mm of translation occur.<sup>39</sup> The amount of joint motion decreases with age. Women develop degenerative changes that restrict motion at age 50 years; men develop them around age 40 years. It is not clear that change in motion at one joint is the source of pain at that joint. Gender differences in flexibility and range of motion that may affect performance have been well documented. Reports indicate that women have greater range of motion and flexibility.<sup>18</sup> This greater range of motion further suggests that relative imbalances in muscle length and strength may place the female athlete at risk for SIJ dysfunction.

Acquired hyper- or hypomobility results in altered load transmission, which may lead to muscle and other joint dysfunction secondary to adaptations. Women develop relative changes in motion based on hormonal fluctuations as well. During pregnancy, estrogen and relaxin play a key role in promoting increased ligamentous laxity. If the secondary stabilizers (musculature of the hip, spine, and pelvis) do not provide the stability needed, the joint may enter a relatively hypermobile state. Estrogen level changes continue in the postpartum period. During this time the supporting musculature is developing new adaptive patterns as a result of the pregnancy and delivery. These circumstances may place the female athlete at greater risk for injury. With aging, degenerative changes direct the joint into a relative hypomobile state. Often, motion lost at the SIJ is attempted to be regained at another joint. Examples include the hip, lumbosacral segments, and pubic symphysis. So although changes in motion at the SIJ may not cause direct injury to the joint, they place peripheral joints at risk for altered adaptive patterns. Changes in adaptive patterns and mechanics may make these joints more susceptible to injury.



**Figure 5.** Biomechanics of motion at the SIJ during walking. Deceleration force provides bracing to support the inertial-gravitational force. Sacrum moves around oblique axis during ambulation. DF = deceleration force; IGF = inertial-gravitational force; OA = oblique axis. (From Cole AJ, Dreyfuss P, Pauza K: Sacroiliac joint injection techniques. In Vleeming A, Mooney V, Dorman T, et al (eds): The Integrated Function of the Lumbar Spine and Sacroiliac Joint: Part II. Second Interdisciplinary World Congress on Low Back Pain, San Diego, November, 1995, p 507; with permission.)

## PAIN AND INJURY

Injuries or pain syndromes that involve the lumbar spine–pelvis–hip complex can present with a wide array of symptoms. Again, the risk factors for such injuries are often sport- or exercise-specific. However, recurrent injury or reinjury may be an indicator of more serious systemic problems. A runner with recurrent stress fractures may have more than an overuse syndrome. Assessing bone mineral density in such patients may reveal underlying systemic problems. Women in particular are susceptible to physiologic changes that put them at risk for low bone mineral density and osteoporosis. For comprehensive care to be initiated, the healthcare provider must be aware of these scenarios.

Pelvic injuries that athletes and exercisers may encounter are outlined in the following paragraphs. A few injuries involving the hip joint will be discussed, because they may present with groin or lower abdominal pain. Hip and pelvic injuries occur in both men and women. Specifics regarding pelvic floor injuries will be limited to the female population. Certainly, men are susceptible to pelvic floor trauma but it is difficult to assess anatomically and biomechanically; as a result little information is available in the literature.

### Bony Injuries

Weight-bearing exercise is protective because it helps build bone mass. Excessive activity increases the risk of stress fracture. Determining what is excessive is specific to the individual's circumstances. Athletes participating in endurance type exercise or sports are at increased risk for these fractures. Bony injuries involving the hip and pelvis may occur because of overuse or trauma. The hip joint accounts for 17% of all athletic injuries, of which the majority are overuse injuries.<sup>22</sup> Stress fractures may occur at various sites, including the ilium, lesser trochanter, femoral neck, pubis, and sacrum. Early diagnosis is important to prevent further injury or complete fracture. Recurrent stress fractures may be a sign of an underlying systemic problem. The healthcare provider needs to investigate reasons other than exercise or sports participation for repeated injury. The adolescent or young adult athlete should be questioned regarding other symptoms of the female triad including amenorrhea and eating disorders. The older female athlete or exerciser should be examined for osteopenia or osteoporosis. Early intervention will decrease the risk of repeated injury.

Other bony injuries to the hip and pelvis often are sustained as a result of high impact or trauma. These include avulsion injuries, acetabular labral tears, and complete fractures. Avulsion injuries occur at the attachment of a tendon or ligament to bone. They occur as a result of a strong and rapid muscle contraction and are seen most commonly in adolescents participating in sports. The most common sites for avulsion injuries include the anterior superior and inferior iliac spines, ischial tuberosity, and iliac crest. Clinically, avulsion injuries present with tenderness at the site of muscle origin and demonstrate weakness of the isolated muscle. Apophysitis has a similar clinical presentation. The latter is an inflammation at the tendon-periosteal junction but with no avulsion of bone. In contrast, apophysitis results from an overuse injury. Radiographs can differentiate the two injuries because a fracture will be identified in avulsion injuries. Apophysitis may be noted on imaging such as bone scan or magnetic resonance (MR) imaging that show edema at the site of injury.

Acetabular labrum tears often result from trauma or repetitive twisting injury. Presenting symptoms include a catching and giveaway sensation in the anterior hip and groin. Pain may occur with pivoting or transitional movements, as when arising from a chair. Clicking may be noted when the hip is passively extended, internally rotated, and adducted.<sup>32</sup> Once radiographs have been completed and show no fracture, an MR imaging arthrogram has a high sensitivity and specificity in identifying labral tears. Laparoscopic hip procedures now provide a minimally invasive definitive treatment in cases in which conservative management has failed.

Avascular necrosis of the femoral head is uncommon in specific sporting or exercise events, but may occur as the result of repetitive trauma. Those athletes at increased risk may have a history of alcohol use or abuse or corticosteroid use. It most commonly occurs in men between 30 and 70 years of age. Clinical presentation includes sudden onset of hip or groin pain and change in gait pattern. Early diagnosis is important in improving long-term outcome. Radiographs may not show the early changes of avascular necrosis, and an MR image should be obtained in suspected cases.

Osteoarthritis is the most common hip disorder in the general population. The cause is multifactorial including familial predisposition, obesity, and history of hip injury or disease. Men and women are equally prone to hip pathology. Recent studies outline concern for the development of an increased risk of hip osteoarthritis in women who participate in sports and exercise. Lane and

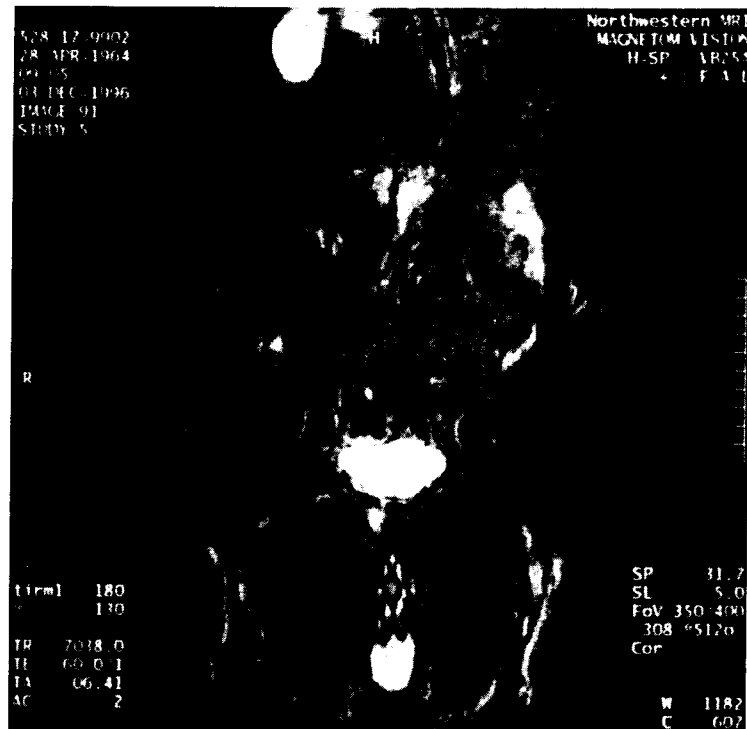
colleagues<sup>20</sup> compared self-reported activity levels and hip radiographic findings and pain in elderly women. Women who exercised more than four times per week had a marginally increased risk of hip osteoarthritis. Vingard and coworkers<sup>36</sup> compared self-reported sports activities in women who underwent total hip replacement for osteoarthritis with control women without hip problems. Those women with high sports exposure were 2.3 times more likely to develop hip osteoarthritis leading to total hip replacement. Both of these studies are retrospective and rely on the subject to recall activity level over a lifetime. Caution should be used in advising women to abstain from physical activity because of the risk of osteoarthritis. Although activity may increase the risk of osteoarthritis, better skill training and prehabilitation for women in the future may show a plateau in the incidence of activity-associated osteoarthritis.

Although hip osteoarthritis may not be caused by a specific sports injury, many exercisers and athletes must overcome the limitations of osteoarthritis to participate. Managing an exerciser with hip pain related to osteoarthritis encompasses possibly altering the type of activity or weight-bearing while trying to restore muscle, fascial, and capsular mechanical balance. Prevention of impairing soft tissue adaptations such as a hip flexion contracture is essential in keeping the exerciser with hip osteoarthritis on the playing field.

Osteitis pubis is a syndrome involving bony change that often occurs as a result of an overuse injury. Pubic symphysis and recurrent groin injuries may, in fact, be precursors of the degenerative changes described as osteitis pubis. Exercisers or athletes participating in repetitive kicking, pivoting, and running are at risk for this injury. Nonathletic risks include previous bladder or prostate surgery or pelvic floor trauma. Symptoms at presentation include groin, anterior hip, and lower abdominal pain. The exerciser may have a recurrent or long history of groin pulls. Antalgic gait and pain on palpation of the pubic symphysis that increases with resisted hip motion are often noted on physical examination. Radiographs may show sclerotic changes but often are normal. A bone scan may show asymmetric uptake at the pubic symphysis. MR imaging is helpful in delineating stress fracture from stress reaction (Fig. 6). Arriving at the diagnosis of osteitis pubis takes coordination of history and physical examination, because adjunct testing is limited. Addressing the pain complaints before radiographic changes occur is essential.

### Soft Tissue, Nerve, and Muscle Injury

Tendonitis, muscle strains, and muscle imbalances are common types of injuries in exercisers and athletes. Muscle and tendon dysfunctions can lead to friction and, at specific sites, cause bursitis. There are several theories regarding the concept of muscle imbalance, which are listed below.<sup>6</sup> Therefore, trauma or injury is not the only way muscle imbalances develop. Janda<sup>16</sup> has studied muscle imbalance and adaptations in children and adolescents. He found a 21% incidence of short muscles in 115 school-aged children. Follow-up examinations at ages 12 and 16 showed that muscle tightness increased and then plateaued. These muscle imbalances did not correct without intervention.<sup>16</sup> Muscles involving the hip and pelvis that are prone to tightness include the iliopsoas, rectus femoris, tensor fascia lata, short adductors, hamstrings, quadratus lumborum, and piriformis. Strains and muscle tears often occur in muscles that are prone to tightness. Tendonitis often occurs in weak, inhibited muscle groups. Examples at the hip and pelvis include the gluteus medius, gluteus maximus, abdominals,



**Figure 6.** MR image of the pubic symphysis showing bony edema in the superior pubic ramus noted by the increased signal on T2-weighted image.

and quadriceps.<sup>12</sup> Identifying muscles that are functioning in a shortened position or are inhibited is key to devising a rehabilitation or prehabilitation.

#### Theoretical Causes of Muscle Imbalances<sup>6</sup>

1. Postural adaptation to gravity
2. Neuroreflexive due to joint blockage
3. Central nervous system malregulation (impaired programming)
4. Response to painful stimuli
5. Response to physical demands
6. Lack of variety of movement patterns
7. Psychologic influences
8. Histochemical differences

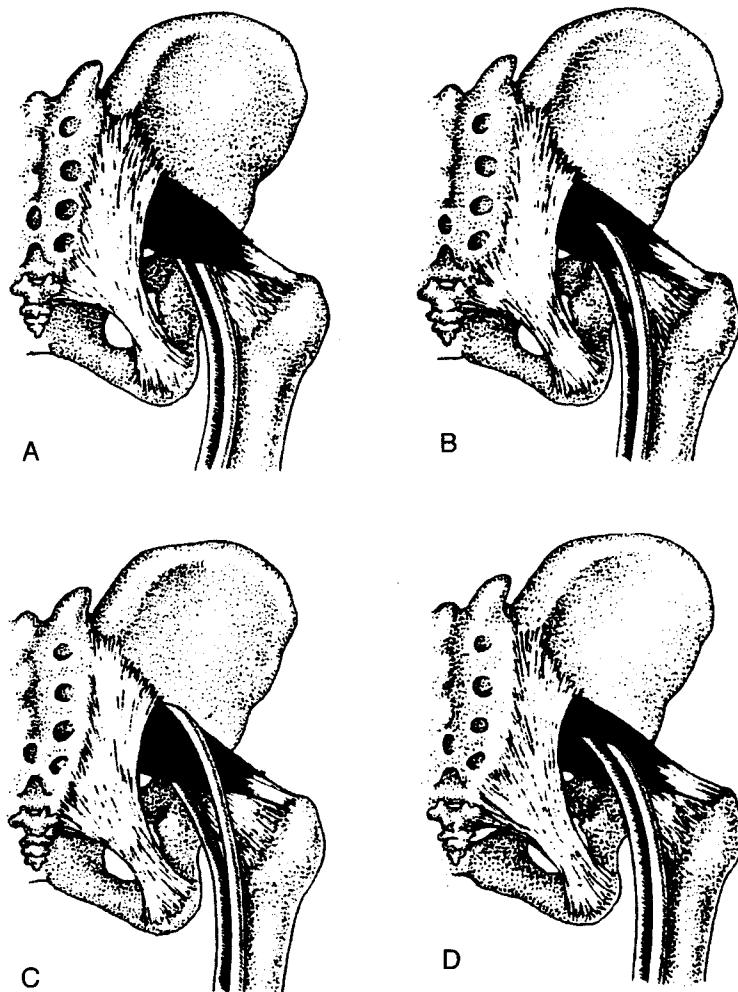
Bursitis also can accompany a primary muscle or tendon dysfunction. A bursa becomes filled with fluid as a result of inflammation that develops because of friction. This friction occurs because a tendon is not able to glide efficiently across a region. This inefficiency may be because of bony protrusions or primary muscle or tendon injury. Common sites for bursitis involving the hip and pelvis include iliopsoas at the ischial pectineal line, greater trochanter of the hip, ischiogluteal area, and origin of the obturator internus. Determining the primary mechanism of injury will facilitate a treatment program and prevent reinjury.

Identifying the mechanism of injury in the history coupled with a comprehensive physical examination leads to a specific diagnosis. The healthcare provider must have a good understanding of muscle balance and function. Subtle imbalances of agonist and antagonist muscle groups are often not found on a standard physical examination. Muscle weakness sometimes cannot be identified unless the muscle is fatigued. Poor endurance in a quadricep may be detected with single leg squats. Hamstring weakness may be noted with repeated wall squats or bridging from a supine position. Examining individual muscle length is also key in forming a specific rehabilitation prescription. If a tight iliopsoas goes unnoticed, a strengthening program for the hamstrings may be fraught with problems. A tight iliopsoas often leads to an anterior pelvic tilt. An increase in anterior pelvic tilt then leads to the hamstrings firing in a lengthened position. Strengthening the hamstrings in a lengthened position may lead to submaximal strength benefit and overload may cause subsequent hamstring injury. Observing quality of motion also is important. Examining lumbopelvic rhythm is an example of observing quality of motion. With forward flexion, the lumbar spine should move initially, followed by the pelvis and hips. Initiation of motion from the pelvis or hip indicates a breakdown in muscle function. Incorrect initiation of motion may be a result of lumbar spine dysfunction or muscle imbalance at the hip and pelvis. Measuring fingertip distance from the floor at end range of forward flexion is not as useful as determining the quality of motion demonstrated to achieve the position. Recurrent muscle and tendon injuries must be carefully reviewed so that an underlying bony or systemic problem is not overlooked. If indeed the injury is recurrent to the soft tissue, the healthcare provider must investigate the mechanism of injury, training patterns, environmental factors, and equipment to ensure complete resolution. Specifying the precise muscle, tendon, or soft tissue involved in an injury leads to a specific treatment program and preventative maintenance program.

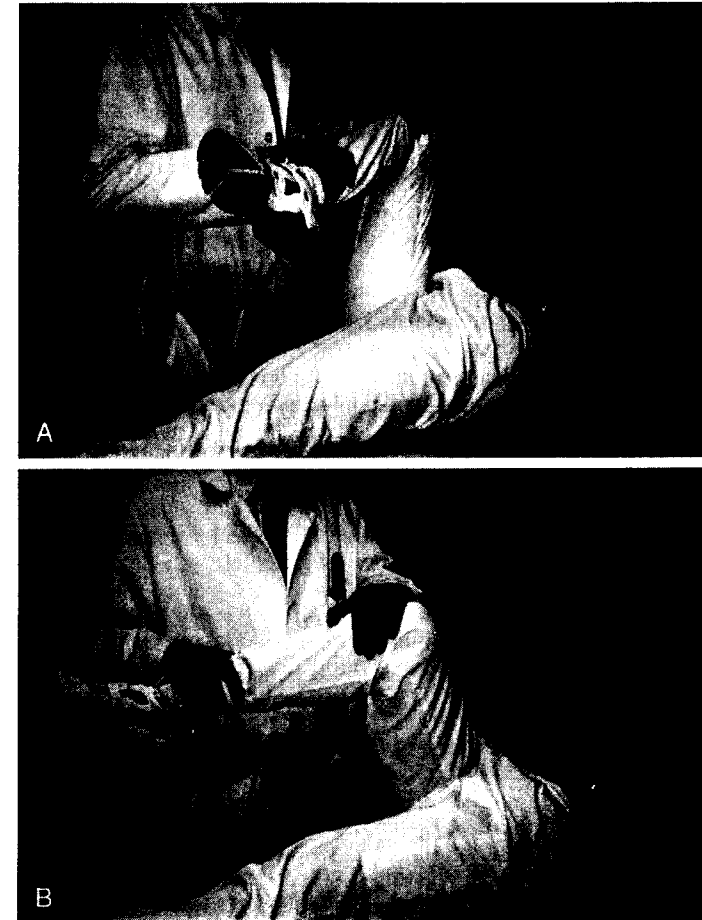
Several specific muscle imbalance syndromes occur at the hip and pelvis. These are sport- or activity-specific. They may present with a wide range of symptoms including pain in the buttocks, groin, lumbar spine, and knee.

Piriformis syndrome may present with a variety of complaints. These include back or buttocks pain, and lower extremity pain or numbness. The true syndrome, by definition, includes electrophysiologic changes along the distribution of the sciatic nerve as a result of compression by the piriformis. The sciatic nerve travels through the sciatic notch and passes anterior to the piriformis 85% of the time (Fig. 7). Variations to this relationship exist. In 10% of the population, the sciatic nerve divides before passing through the gluteal region. The common peroneal portion passes through the piriformis and the tibial portion passes anterior to the piriformis. In 2% to 3% of cadavers, the peroneal portion loops superior and posterior to the piriformis and the tibial portion travels anterior to the muscle. Another variation, found in fewer than 1% of the cadavers, is an undivided nerve that passes through the piriformis. Regardless of its position, the sciatic nerve is vulnerable to compression or irritation at the site of the piriformis.

The piriformis facilitates different motions at the hip based on the position of the hip. In hip extension, the piriformis is an external rotator of the hip. In 60° of hip flexion, the piriformis is an abductor. With the hip positioned at 90° of flexion, the piriformis internally rotates the hip.<sup>17</sup> Because the muscle performs different motions in different hip positions, the examiner must include different positions to fully examine the muscle (Fig. 8). An imbalance in muscle length and strength may create a dysfunction, resulting in pain. The author postulates that a number of patients present with a symptom complex related to piriformis



**Figure 7.** Four different positions of the sciatic nerve in relation to the piriformis muscle. *A*, The commonest route; the nerve passing anterior to the piriformis. *B*, Peroneal portion of the nerve passing through the muscle and the tibial portion passing anterior to the muscle. *C*, The peroneal portion passing anterior and superior over the muscle and the tibial portion passing anterior and inferior to the muscle. *D*, Both portions of the sciatic nerve passing through the muscle. (From Travell JG, Simons DG: *Myofascial Pain and Dysfunction: The Trigger Point Manual: The Lower Extremities* vol 2. Lippincott, Williams, and Wilkins, Baltimore, 1992, p 201; with permission.)



**Figure 8.** It is important to test strength and flexibility of the piriformis muscle with the hip positioned in different angles. *A*, Hip flexed at 90° with examiner testing flexibility by externally rotating hip. *B*, Examiner testing flexibility with hip flexed at less than 90°.



dysfunction without electrophysiologic changes on electromyography. Lack of electromyographic changes may be a result of inherent muscle weakness or may occur because neurogenic compression is only intermittent. Piriformis irritability and dysfunction may occur even though electrodiagnostic testing results do not fulfill the criteria for piriformis syndrome. Even if test results do not meet the definition of piriformis syndrome, the area needs to be treated to prevent further regional breakdown in mechanics. A painful piriformis by history and on physical examination may be part of a symptom complex of another regional diagnosis. Examples include L5 to S4 radiculopathy, intrinsic hip pathology, and SIJ dysfunction. These areas need to be further investigated so as not to incompletely treat the athlete or exerciser. Activities that require one-legged activity or stance such as bowling or skating may place the athlete at risk for pain associated with the piriformis muscle. Shifting from one extremity to the other in activities like running and using a stairstepper may also increase the risk for breakdown in mechanics.

The exerciser may present with low back, buttocks, and lower extremity pain or numbness. Lower extremity symptoms may not pass far beyond the gluteal fold or may involve the foot. On examination, pain with palpation of the muscle may be noted, and pain may be further exacerbated with stretch or with resisted activation. The examiner must be careful to stretch and activate the muscle according to the function it performs in different hip positions. Specific positioning for testing relative muscle strength and length is essential to formulate a specific rehabilitation plan. Positioning also may reveal symptoms other than pain such as numbness or tingling, which should be noted. Further internal palpation by a rectal examination can help clarify the clinical diagnosis in questionable cases. Muscle stretch reflexes and sensory deficits may be reduced in the tibial or peroneal distribution.

Snapping hip syndrome is another common symptom complex that afflicts exercisers and athletes. A snapping or clicking sensation during activity may be associated with pain. The cause of the click is site-specific. The most common cause is the hip suction phenomenon. Other intraarticular causes that should be carefully ruled out include subluxation, acetabular labral tear, loose body, and osteochondromatosis. Other common tendon causes include the iliopsoas snapping over the iliopectineal eminence and the iliotibial band moving over the greater trochanter. Pubic symphysis instability may present with clicking in the groin region. The instability may be related to trauma such as that experienced with childbirth or generalized ligamentous laxity. Determining the site of the clicking is important but can be difficult. The examiner should palpate the area of the snapping during active and passive hip range of motion to distinguish the structure.<sup>11</sup> Regional muscle imbalance should be considered once the source of snapping has been determined. The iliotibial band may tighten because the muscle is serving as a hip abductor as the result of an inhibited gluteus medius. The healthcare provider should not expect the snapping hip syndrome to remain resolved solely with iliotibial band (ITB) stretching. Gluteus medius strengthening in the appropriate hip position will allow the ITB to remain in its new lengthened position.

Other sources of pain and dysfunction include muscle imbalances causing relative overuse syndromes. Janda and colleagues<sup>16</sup> have described a muscle imbalance syndrome at the hip and pelvis as the pelvic crossed syndrome. This includes a muscle imbalance pattern of tight hip flexors and hamstrings with inhibited glutei and lumbar erector spinae muscles. Quality of muscle activation and firing patterns are noted. An example includes noting the succession of muscle firing in hip extension from the prone position. The order of firing involves the ipsilateral hamstring, gluteus maximus, contralateral lumbosacral

paraspinals, contralateral thoracolumbar paraspinals, and finally the ipsilateral thoracolumbar paraspinals. Commonly, the gluteus maximus is weak and fires late in the sequence, which may then allow breakdown somewhere proximal or distal such as the lumbar spine or hip.<sup>16</sup>

Sahrman<sup>29</sup> describes a series of muscle imbalances at the hip called hip impingement syndromes. Anteromedial impingement presents with groin pain with hip flexion and posterior pain with weightbearing. On physical examination there is anteromedial displacement of the greater trochanter when the knee is moved to the chest. With hip extension, hamstring activity is dominant over gluteus maximus. Tightness may be found in the tensor fascia latae. Anterolateral impingement presents with hip pain with weight bearing, which is relieved with external rotation of the lower extremity in stance. As a result, hip external rotators and hamstrings are tight. Proximal impingement syndrome is diagnosed in individuals presenting with complaints of deep hip pain and pain on palpation lateral to the tensor fascia lata. Pain may be described in the inner thigh region. The exerciser may complain of early morning stiffness or discomfort that increases with activity. Decreased range of motion is found in a capsular pattern, including decreased hip flexion and internal rotation. Tightness is found in the iliopsoas, rectus femoris, and tensor fascia lata. Osteoarthritis is often found in association with this hip impingement syndrome.

Muscle contusions should be identified early in the athlete so as to rule out underlying bony injuries. A contusion usually develops as a result of a direct blow or trauma. A hip pointer occurs as a result of a blow to the anterior iliac crest. A tear to the muscle aponeurosis or avulsion of the apophysis should be excluded. Myositis ossificans also may develop as a result of muscle trauma. The athlete may present with hardening of the hematoma and decreasing range of motion. Osteoblasts form within the hematoma to replace the fibroblasts in the traumatized muscle. Calcification within the muscle belly may be seen as early as 7 to 10 days after the injury on radiographs. The individual usually complains that pain occurs with concentric muscle contraction or passive stretch. Heterotopic bone growth may be evident between 2 and 3 weeks after the trauma. Bone scan may give positive results before changes are found on radiographs.

Neurogenic pain should be considered in the differential diagnosis for pelvic and groin pain. Meralgia paresthetica is one common nerve entrapment that occurs at the pelvis. The lateral femoral cutaneous nerve is entrapped in the pelvis as it crosses the groin medial to the anterosuperior iliac spine. Fibrous tunnels may exist that the nerve or branches may cross through. Overweight or pregnant exercisers are at increased risk for developing an entrapment. Nerve conduction studies are helpful in confirming the diagnosis. Reducing equipment or clothing restrictions at the hip and groin can be helpful in reducing symptoms. Other neurogenic causes for pain at the groin and pelvis include high lumbar radiculopathy, entrapment of the genital branch of the genitofemoral cutaneous nerve, obturator nerve entrapment at the pelvis, and pudendal nerve injury should be excluded. Previous trauma or spine or pelvic surgery may place the individual at increased risk for these problems. Pudendal nerve injury in particular can lead to a number of pelvic floor dysfunctions described elsewhere in this article.

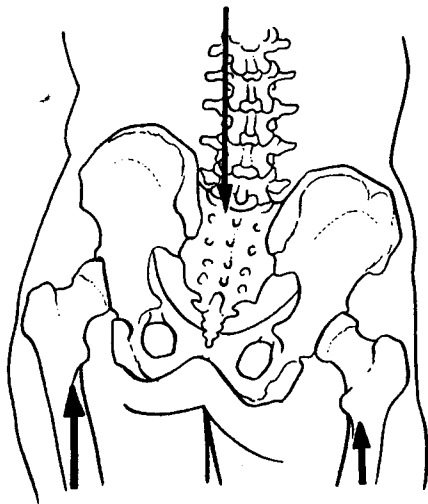
### Sacroiliac Joint Dysfunction

The SIJ is a controversial instigator of pain and dysfunction. Reasons for controversy are multifactorial. The joint is narrow with only a few degrees of

motion and degenerates with aging, losing further motion.<sup>39</sup> The biomechanics regarding the joint are complex. Research is ongoing regarding joint mechanics and load transmission. There are no specific standards for evaluation of SIJ dysfunction, and often SIJ dysfunction is a diagnosis of exclusion. Imaging of the joint commonly reveals changes associated with aging but does not distinguish asymptomatic from symptomatic individuals. For women, SIJ pain and dysfunction may be underdiagnosed because of coexisting gynecologic problems or because of pelvic changes that occur during and after pregnancy.

The prevalence of SIJ pain is unknown. Bernard and colleagues<sup>3</sup> reported that of 1293 patients with low back pain, SIJ dysfunction was thought to be the pain source in 22.5% based on history and physical examination. Another study showed that 58% of those individuals with SIJ dysfunction by history and physical examination had a history of trauma.<sup>4</sup> Sports and training equipment that require repetitive unidirectional pelvic shear and torsional forces may be important risk factors for SIJ dysfunction (Fig. 9). These sports include skating, gymnastics, golfing, and bowling. Asymmetric shear forces can be distributed through the SIJ during the use of a stairstepper, elliptical trainer, or workouts including step aerobics.

SIJ dysfunction may present in various patterns. Athletes commonly complain of pain in the low back or buttock near the posterior superior iliac spine. Pain may radiate down the posterior leg or anterior groin. Pain may be exacerbated with repetitive overload activity, transitional movements, and unsupported sitting. There are no specific examination techniques or diagnostic tests that consistently or accurately identify SIJ pain. The examiner must have a clear understanding of biomechanics and process through a multi-item differen-



**Figure 9.** Asymmetric force transmission through the pelvis via the lower extremities or trunk place athletes at risk for SIJ dysfunction. Arrows indicate vertical diverging forces from above (*trunk force*) and from below (*ground force*). (From Portersfield JA: Conditions of weight bearing: Asymmetrical overload syndrome (AOS). In Vleeming A, Mooney V, Tilscher H, et al (eds): *The Most Effective Role for Exercise Therapy, Manual Techniques, Surgery and Injection Techniques*. Third Interdisciplinary World Congress on Low Back Pain, Vienna, Austria, November, 1998. p 253; with permission.)

tial diagnostic evaluation. SIJ dysfunction is often determined by exclusion. Physical examination should include the usual gait analysis and neurologic, postural, joint range of motion, flexibility, and strength evaluation.

Gillet's test assesses side-to-side ilial-sacral motion. Lack of posterior rotation of the ilium on single leg stance indicates an alteration in range of motion. This is not necessarily indicative of the side of pain or dysfunction (Fig. 10). Observation and palpation of bony landmarks in weight-bearing and nonweight-bearing positions are important. Asymmetric lumbopelvic rhythm in standing or sitting can help identify problem areas to address. Determining if a functional or anatomic leg length discrepancy exists is necessary. Patients often have pain on palpation along the posterior superior iliac spine (PSIS) and sacral sulci. Provocative testing such as Gaenselen's test, Patrick's test, or pelvic compression may help direct the diagnosis, but a negative test result does not exclude SIJ dysfunction.

The differential diagnosis of SIJ pain is all encompassing. Inflammation of the SIJ may occur as a result of metabolic changes, arthritis, trauma, or infection. Primary tumors of the SIJ are rare. Iatrogenic instability may result from graft harvesting. Osteitis condensans, increased density on the ilial side of the inferior SIJ, occurs in 2.2% of the multiparous female population and is usually self-limiting. Sacroiliitis may develop as a part of pelvic inflammatory disease. Changes that occur during pregnancy, as described previously, must be considered. Pain may be referred from other sites of dysfunction, including lumbar diculopathy, lumbar facet joint pain, lumbar central or lateral recess stenosis, lumbar discogenic pain, hip disease, and Maigne's syndrome. Radiographs of the SIJ are important to rule out infection, metabolic changes, fracture, or tumor. Computed tomography (CT), MR imaging, bone scan, or single photon emission computed tomography (SPECT) provides more detailed information regarding the joint. Rarely will imaging clearly define SIJ dysfunction. The healthcare provider must consider the information gained from the history and correlate it with clinical observation to arrive at the diagnosis. The physical examination includes noting subtle changes in flexibility, strength, and eliminates neurogenic causes of the pain. When clarification is necessary, diagnostic fluoroscopically guided sacroiliac joint injection can be helpful in confirming the diagnosis.



**Figure 10.** Gillet's test facilitates measuring side-to-side ilial-sacral motion. The examiner places both thumbs on the PSIS and assesses posterior ilial rotation with hip flexion. With posterior ilial rotation the PSIS should move inferiorly.

## Pelvic Floor Dysfunction

Pelvic floor pain and dysfunction can cause considerable impairment for the female exerciser and athlete. Unfortunately, sports literature rarely focuses on such problems and is often left as a gynecologic problem. The pelvic floor is a group of muscles that must act in coordination with their surrounding joints including the lumbar spine, SIJ, hip joint, and pubic symphysis. In addition, the pelvic floor must function in coordination with visceral structures, including the bladder, vagina, uterus, ovaries, and colon. The muscles of the pelvic floor may respond adaptively to a primary visceral problem. An example is an increased muscle tone that may occur in the levator ani on the ipsilateral side of an ovarian cyst. The athlete may present with primary complaints of pelvic pain with urination, defecation, intercourse, or around the time of menstruation. Primary hormonal dysfunction, visceral problem, and infection should be ruled out. When the listed problems are excluded, determining the musculoskeletal dysfunction will facilitate recovery and treatment program.

**Pelvic Floor Pain Dysfunctions.** Adaptive patterns in the pelvic floor can develop as a result of a primary joint injury. A hip with osteoarthritic changes and loss of range of motion may refer pain to the groin and pelvic floor. Muscle guarding may occur, causing increased tone within the pelvic floor. Increased muscle tone within the pelvic floor may lead to pain and dyssynergic problems. Primary muscle imbalances also can refer or cause subsequent pelvic floor muscle imbalance. An athlete with piriformis syndrome with an inhibited gluteus medius may develop obturator internus pain noted in the pelvic floor. The obturator internus acts as a secondary hip abductor. Overload may occur because of the inhibited gluteus medius with resultant obturator internus pain. Pelvic floor myofascial pain in female exercisers and athletes is often associated with asymmetrical tautness in the sacrotuberous ligament and the surrounding muscles and fascia. Facilitating muscle tone symmetry is key for appropriate treatment. Because overlap exists in hip, back, and pelvic injuries and dysfunction, the biomechanics of the pelvic floor should be addressed just as they are addressed for an external pelvic dysfunction.

Tension myalgia is another label often given to general pelvic floor pain. Diagnoses included under this heading include piriformis syndrome, levator ani syndrome, coccydynia, and vagismus. Dysfunctions involving increased muscle tone of the musculoskeletal and urogynecologic systems are often referred to as levator ani syndrome. Increased pelvic floor muscle tone may be an adaptive component to other primary dysfunctions, including low back pain, chronic pelvic pain with negative laparoscopy results, endometriosis, interstitial cystitis, urethral syndrome, and sphincter dyssynergia. Women often present with pain in the general region of the vagina, rectum, lower abdominal quadrants, and posterior pelvis. Other areas of discomfort can include the coccyx, pubic symphysis, and posterior thigh. Functional limitations because of pain often are reported. These limitations include dyspareunia, sexual dysfunction, and difficulty with voiding and constipation. Urinary frequency and urgency may be present.

Increased muscle tone in the pelvic floor may occur for several reasons; direct trauma to the pelvis, as with fractures or joint injuries involving the hip, ilium, and sacrum, may be responsible. Abnormal use or adaptive muscle imbalance syndromes can contribute to increased pelvic floor muscle tone. Myofascial pain syndromes may develop primarily or secondary to trauma or muscle imbalance. Travell and Simons<sup>35</sup> have identified specific pelvic floor

muscles that may cause symptoms. Trigger points within these muscle groups can refer pain.

Pelvic floor muscles susceptible to trigger point formation resulting in pelvic pain<sup>35</sup>:

- Coccygeus
- Levator ani
- Obturator internus
- Adductor magnus
- Piriformis
- Oblique abdominals

Muscles susceptible to trigger point formation resulting in iliosacral pain:

- Coccygeus
- Levator ani
- Gluteus medius
- Quadratus lumborum
- Gluteus maximus
- Multifidi
- Rectus abdominus
- Soleus

A history of sexual abuse, anxiety, depression, and general lifestyle stress can cause muscle tension.<sup>41</sup> Concomitant evaluation of psychosocial factors is imperative to evaluate and treat the pain syndrome comprehensively.

Evaluations for pelvic floor dysfunctions involving increased muscle tone include a manual examination of the pelvic floor and musculoskeletal, neurologic, and posture evaluation. The internal and external pelvic floor examination identifies the specific location of the pain. The musculoskeletal and neurologic examinations of the hip, pelvis, and lumbar spine help identify primary or secondary causes for pelvic floor pain. Surface electromyography (EMG) biofeedback evaluation performed with internal and external electrodes is helpful in determining baseline resting muscle activity. Tone changes that occur with position changes, exercise, or functional activities can also be identified.

Pelvic floor muscle dyssynergia is another cause of pelvic floor pain. Muscles must fire at the appropriate place, time, and intensity. If muscles are unable to coordinate contraction and relaxation, dysfunctions in micturition and defecation may occur. This complex of symptoms is referred to as pelvic floor dyssynergia. Several causes for pelvic floor dyssynergia exist. Pudendal nerve injury can result in sensory and motor deficits inhibiting appropriate muscle functioning. Improper technique during exercise that causes a bearing down on the pelvic floor rather than lifting of the pelvic floor can facilitate dyssynergia. Other neurologic diseases or injury and inability to isolate pelvic floor muscle contractions from abdominal or gluteal muscle contractions can lead to muscle incoordination and dyssynergia.<sup>42</sup>

**Treatment of Pelvic Floor Pain Dysfunctions.** When infection and other serious medical causes have been ruled out, hypertonic pelvic floor muscle pain should be managed by addressing psychologic, neurochemical, and mechanical factors. Physical therapy can address specific muscle imbalances with appropriate flexibility and strengthening exercises. Various techniques such as myofascial release, muscle energy, joint mobilization, and posture education can be incorporated. Surface EMG biofeedback is helpful in identifying the muscles with increased tone and facilitates relaxation techniques used to reduce tone. Modalities such as heat and cold may facilitate pain management and relaxation.

When indicated, medications addressing neurogenic pain, sleep dysfunction, anxiety, and depression should be used concomitantly with physical therapy.

Pelvic floor biofeedback is especially helpful in the treatment of pain syndromes related to dyssynergia. Biofeedback facilitates coordination of muscle contractions at rest and during activities of daily living. Physical therapy must focus on retraining pelvic floor muscle activity with proper breathing. This is especially important for the athlete performing high-resistance exercise such as weight lifting, rowing, and bicycling. Activities of daily living involving childcare should be evaluated. During the months after childbirth, lifting and carrying the child may facilitate a dyssynergic syndrome. Controlling contraction of the pelvic floor during exhalation facilitates the pelvic and respiratory diaphragms to act in synergy. A physical therapist can help facilitate training the pelvic floor to contract before lifting, laughing, or coughing. Medications for neurogenic causes may be indicated. Care must be taken to avoid medications that may adversely affect bladder function.

**Urinary Stress Incontinence.** Urinary stress incontinence is another pelvic floor dysfunction that adversely affects female athletes. Nygaard and colleagues<sup>25</sup> surveyed 144 nulliparous elite female athletes and found that 28% reported stress urinary incontinence during exercise or sports participation. Of the athletes studied, gymnasts and tennis players reported a higher incidence of urine loss. The cause of incontinence in athletes is thought to be multifactorial. Contributing factors include inadequate abdominal pressure transmission, pelvic floor muscle fatigue, and changes in collagen or connective tissue.

High-impact sports that require jumping and landing may place participants at greater risk for incontinence because of the sudden increase in intraabdominal pressure. The pelvic floor muscles must be able to contract with enough speed and force to withstand repetitive deceleration of the visceral structures within the abdomen onto the pelvic floor. The levator ani in particular must have sufficient endurance and strength to support the pelvic organs in humans because of the upright posture.<sup>10</sup> The chronic pressure of gravity on the pelvic floor is rapidly increased with coughing, sneezing, running, and jumping. Despite ongoing investigations, the question remains as to whether athletes have stronger pelvic muscles or connective tissue because of long-term increases in intraabdominal muscles. In another study Nygaard<sup>27</sup> surveyed previous female Olympic swimmers, gymnasts, and track and field participants from 1960 through 1976. The survey focused on the prevalence of urinary incontinence. The athletes were between 42 and 47 years of age at the time of the survey. No differences were found between athletes participating in high- or low-impact sports. Of the 104 responders, 8% and 10% of each group, respectively, reported daily or weekly incontinence. Therefore, a significant number of the athletes were reporting incontinence later in life regardless of the type of impact sport. With further investigations, the risk associated with exercise and sports may be found to be activity-specific rather than associated with exercise in general.

Stress incontinence also occurs in nulliparous women without obvious risk factors associated with activity. Bo and colleagues<sup>5</sup> found that nulliparous women with stress incontinence had a reduction in tissue collagen concentration as compared with controls. Another study by Al-Rawi and colleagues<sup>1</sup> showed connective tissue differences in controls and women with genital prolapse. Sixty percent of the group with prolapse had joint hypermobility as compared with 18% of those without prolapse. Collagen architecture or collagen changes related to aging place women at risk for incontinence. The collagen changes may cumulate with the stress of high-impact activities during sports or exercise, resulting in stress incontinence.

In addition to the risks outlined previously, the female athlete or exerciser who has given birth may have other contributing factors to the development of incontinence. Several studies<sup>2, 12, 33, 34</sup> have shown significant denervation in pelvic floor muscles in women who have given birth vaginally. Denervation with subsequent muscle weakness requires adaptations in muscle function and tone to make up for the loss. Such adaptations may put the woman at risk for incontinence and for myofascial pain syndromes.

Urinary incontinence also occurs in the nonelite athlete and general exerciser. Often this dysfunction goes under- or unreported. Healthcare providers need to be made aware of such problems so that they may be better addressed. In addition to the risk factors identified earlier, the athlete who is amenorrheic or having irregular menstrual cycles may have low estrogen levels. Low estrogen levels can contribute to the development of incontinence. The importance of completing a directed, detailed history cannot be overemphasized. Women may need to be asked if they experience incontinence. Healthcare providers should not leave it to women to report the problem.

Once stress incontinence during exercise has been identified, a thorough evaluation should ensue. Evaluation of other medical problems and medications that may predispose the woman to incontinence is necessary. A voiding diary is helpful in determining the individual's voiding and drinking patterns. This diary can record the types of beverages consumed and the number of incontinence episodes. The urine should be evaluated for infection with a urine dipstick test. Bladder catheterization should be completed within 5 min of voiding to measure residual volume after voiding. A normal postvoid residual volume helps to rule out a voiding dysfunction. Assessing S2 to S4 sensation by pinprick, findings of pressure, and vibration along the vulva, perineum, and inner thighs is important to detect or rule out a subclinical neuropathic process or injury. A general speculum examination by the primary care physician or gynecologist should be completed to rule out other medical reasons for urinary dysfunction. Palpation of the pelvic floor is important to assess muscle tone, strength, and coordination. The individual pelvic floor muscles should be palpated and their tone compared from side to side. Muscle strength of the pelvic floor musculature should be evaluated. There are several grading systems that describe muscle strength from absent to strong. The grading scale, developed by Laycock,<sup>21</sup> measures pelvic floor muscle strength on a scale of 0 to 5.

- 0 none
- 1 flicker
- 2 weak
- 3 moderate
- 4 good
- 5 strong

The examiner measures length of contraction up to 10 seconds, records the number of repetitions up to 10, and records the number of fast 1-sec contractions. Chiarelli<sup>7</sup> also graded pelvic floor muscle strength.

- 0 no contraction
- 1 flicker, only with the muscle stretched
- 2 a weak squeeze, 2-sec hold
- 3 a fair squeeze, definite "lift"
- 4 a good squeeze, good hold with "lift," repeatable
- 5 a strong squeeze, good lift, repeatable

The examiner must observe the individual's ability to contract the pelvic floor muscles without using accessory muscles and without bearing down. This muscle examination helps to determine if the woman will be a good candidate for pelvic floor exercises. A specific physical therapy prescription can then be written indicating if too much or too little muscle tone, strength, or coordination is the problem. If the woman reports urgency, frequency, or dysuria in the absence of infection, referral for urethrocytostcopy may be indicated. Other indications for referral include women with a history of smoking or those who are found to have microscopic hematuria. Full urodynamic testing is indicated when conservative treatment fails, voiding dysfunction is found, or there is a history of pelvic surgery or radiation therapy.

**Treatment of Urinary Stress Incontinence.** Treatment for urinary stress incontinence is tailored to the individual and her lifestyle. Lifestyle measures, support devices, and specific pelvic floor exercises are helpful in managing women whose incontinence occurs primarily during sports and exercise.

Voiding prior to exercise can be suggested if the exerciser with incontinence is not already doing so. Eliminating coffee and caffeine 2 to 3 hrs before exercise can prevent diuresis, thereby decreasing bladder filling. Some women may have already severely reduced their fluid intake before exercise in attempts to decrease their incontinence. These women should be counseled on the need for proper hydration to prevent severe complications that may arise with dehydration.<sup>31</sup>

Several types of intravaginal support devices are available and can be worn during exercise to help eliminate incontinence. Intravaginal pessaries and tampons have been found to be effective in up to 83% and 57% of users, respectively. Successful reduction in incontinence was correlated with the severity of the incontinence.<sup>26</sup> The Introl (UroMed Corporation, Hopkinton, MA) bladder-neck-support prosthesis is similar to a pessary but has projections that fit under the urethra to support it. This prosthesis was found to be 83% effective in one clinical trial.<sup>14</sup> All of these devices help to prevent incontinence by supporting the bladder neck and urethra; however, their effectiveness is not universal.

There are several barrier devices that can be useful in controlling incontinence during exercise. These are placed on the external urethral meatus and are secured by adhesive material or suction. Barrier devices work by obstructing the external urethral meatus. They can be somewhat cumbersome because they must be removed in order to void.

Education in pelvic floor muscle relaxation, coordination, and strengthening is vital for the treatment of urinary stress incontinence in women in whom overflow incontinence or other voiding dysfunction has been ruled out. Instructing the patient in relaxation techniques to counteract increased pelvic floor muscle tone can easily be started during the internal palpatory pelvic examination. Adding biofeedback can be especially helpful. This technique facilitates the patient's awareness of a physiologic change as a response to a voluntary action and assists control of muscle tone. The examiner by commenting on the strength of a muscle contraction during the pelvic examination, can accomplish biofeedback. More sophisticated forms include external perineal and intravaginal monitors that allow the patient to visualize the magnitude of their contraction or relaxation effort on a monitor. This equipment requires specific education in its use and can be expensive. Many companies offer rental programs to support an individual's temporary needs. Facilitating muscle coordination also is important in the treatment of incontinence. The patient must be educated in the sequence of muscle contraction and relaxation with activities of daily living, voiding, and

defecation. An example is the importance of contracting the pelvic floor muscles without performing a Valsalva maneuver. The latter increases intraabdominal pressure thereby increasing the amount of force required by the pelvic floor muscles to contract.

Contraction exercises are often used to increase tone and strengthen the pelvic floor muscles. Healthcare providers should be careful in their recommendations for strengthening exercises in the setting of incontinence. Stress urinary incontinence is not always associated with weak pelvic floor musculature. Often, dysfunction in muscle tone and coordination can be determined. If these are not first addressed, the patient may waste time attempting to strengthen muscles that are either not weak or have not been reset to their appropriate physiologic length to accomplish strengthening. When weakness has been determined to be a part of the dysfunction, patients should be instructed in the proper technique during the palpatory physical examination. Close monitoring is needed to ensure follow-through and problem solving. A strengthening program should be individualized to the patient's needs. A program might include a series of 5-sec contractions followed by 10 sec of relaxation performed for 10 min per day. The program may be upgraded by increasing duration and intensity as the patient's accomplishments progress. When satisfactory strength has been achieved, a maintenance program should be created to deter future recurrences. Vaginal cones may be used to facilitate vaginal strengthening. The patient can use a set of cones of various weights. Starting with the lightest cone, the patient holds it in the vagina for approximately 20 min one to two times per day. As the muscles become stronger, the cone is changed to a heavier weight.

Electrical stimulation is another technique that can be used in the treatment of stress urinary incontinence. This is a device that is inserted into the vagina and delivers a current. The current's amplitude and frequency are adjusted to the patient's comfort and sensitivity. The current produces an involuntary contraction of the pelvic floor muscles. Electrical stimulation may be useful in assisting in the retraining and strengthening of these muscles. Several studies have shown this adjunct treatment device to be effective.<sup>24, 30</sup>

Though urinary stress incontinence involves visceral structures, primary or secondary musculoskeletal dysfunctions are often identified. These need to be fully evaluated, and treatment specified to the type of muscle imbalance, coordination, or tone problem. Incontinence has many social implications. Accurate and early diagnosis in the female athlete can prevent a progressive problem that might deter the woman from participating in exercise or sports.

## REHABILITATION

The goal of a rehabilitation program for the exerciser and athlete is to return to the activity or sport without symptoms and improved functional mechanics. Achieving this goal requires a treatment plan that addresses the primary functional deficit and adaptive changes beyond resolution of symptoms. An appropriate program will focus on muscle and joint physiologic restoration. Ultimately this focus should prevent reinjury and future muscle imbalance. Pelvic pain and dysfunction rehabilitation includes restoration of lumbar spine, hip, and pelvic mechanics. Success in treatment relies on a specific and accurate diagnosis. The rehabilitation model that incorporates the injury cycle and negative feedback described by Kibler and colleagues<sup>18</sup> and Herring<sup>15</sup> is followed. Kibler and colleagues<sup>19</sup> outlined three stages of rehabilitation.

### Acute stage of rehabilitation

- Focus of treatment
  - Clinical symptom complex
  - Tissue injury complex
- Tools
  - Rest and/or immobilization
  - Physical modalities
  - Medications
  - Manual therapy
  - Initial exercise
  - Surgery
- Criteria for advancement
  - Pain control
  - Adequate tissue healing
  - Near normal range of motion
  - Tolerance for strengthening

### Recovery stage of rehabilitation

- Focus of treatment
  - Tissue overload complex
  - Functional biomechanical deficit complex
- Tools
  - Manual therapy
  - Flexibility
  - Proprioceptive neuromuscular control training
  - Specific, progressive exercise
- Criteria for return to play
  - No pain
  - Complete tissue healing
  - Essentially pain-free range of motion
  - Good flexibility
  - 75% to 80% or greater strength, as compared with uninjured side, and good strength balance

### Functional stage of rehabilitation

- Focus of treatment
  - Functional biomechanical deficit complex
  - Subclinical adaptation complex
- Tools
  - Power and endurance exercise
  - Sports-specific functional progression
  - Technique/skills instruction
- Criteria for return to play
  - No pain
  - Full pain-free range of motion/normal flexibility
  - Normal strength and strength balance
  - Good general fitness
  - Normal sports mechanics
  - Demonstration of sport specific skills

### Bony Injuries

**Acute Phase (1–3 Days).** Bony injuries excluding complete fractures are discussed. During the acute phase of recovery the clinical symptom complex and tissue injury complex are addressed with measures to decrease weight-bearing and edema. Weight-bearing on the lower extremity should be as tolerated. Crutches may be necessary in the initial stage. Pubic rami stress fractures or overuse injuries resulting in bony edema seen on MR images or bone scan can be particularly painful. Ice and antiinflammatory medications will facilitate control of swelling and pain. Isometric muscle contractions around the involved joint will provide compression to the joint and decrease the deleterious effects of immobilization. For pubic rami injuries, lower abdominal, adductor, and pelvic floor isometric exercises that do not cause pain are helpful. The exerciser or athlete can advance to the recovery phase of healing once pain and swelling are controlled, near-normal range of motion is achieved, and strengthening is tolerated. For pubic rami or iliac crest injuries, pain-free range of motion at the hip and lumbar spine is necessary. Weight-bearing is advanced as pain allows.

**Recovery Phase (3 Days to 8 Weeks).** The tissue overload complex and functional biomechanical deficit complex are further addressed during the recovery phase. Flexibility of the capsule and muscles surrounding the hip is important. Particular attention should be given to the iliopsoas and hip adductors, because muscle tightness here can lead to tightening down of the capsule. If full weight-bearing is painful, flexibility strengthening exercises can begin in a pool program. Cardiovascular training can continue in the pool too. Once full-weight bearing is achieved, lower extremity balance and proprioceptive training can be accomplished. Trunk stabilization and closed kinetic chain strengthening exercises for the lower extremity are added. Advancement to the maintenance phase takes place when the athlete or exerciser is pain-free with impact activities, bony healing is complete, range of motion and flexibility are restored, and strength has returned to 75% of baseline. Appropriate radiographic imaging is required to ensure bone healing.

**Maintenance Phase.** The functional biomechanical deficit complex and subclinical adaptation complex are addressed. Sports- and exercise-specific activities are advanced. Power and endurance strengthening are tailored to the individual's goals. Review of training schedule and techniques is important during this phase. Further ergonomic evaluation and equipment use (shoes, orthotics, and so forth) should be completed. Trial of return to activity under the supervision of a physical therapist is especially helpful in problem solving. Exercisers or athletes can return to play if they remain pain-free with full range of motion, normal strength and balance, and demonstrate good mechanics while performing the activity. Appropriate radiographic imaging should be completed as indicated to follow the progression of bony healing.

### Sacroiliac and Pelvic Dysfunctions

**Acute Phase (1 to 3 Days).** Acute injury is often associated with a fall or marked increase in intensity, frequency, or duration of a specific activity. More commonly, this dysfunction is progressive with fluctuations in symptoms.

The athlete may only experience symptoms during sports or exercise participation. In the acute setting, antiinflammatory agents and icing are helpful. Relative rest after an acute injury assists with pain management. Rest means

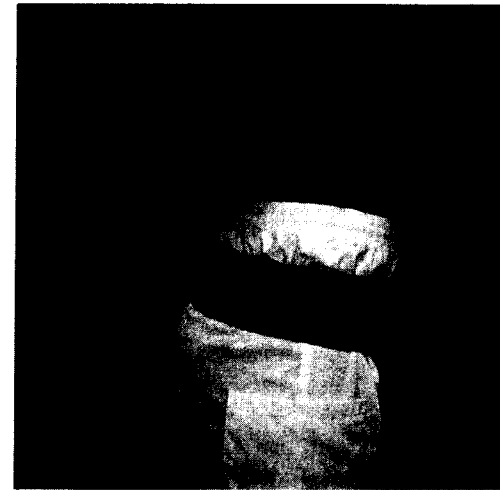
running and excessive walking should be limited because these activities often provoke SIJ pain. Identifying the activity that may aggravate symptoms is important, especially in those individuals with a progressive onset of symptoms. In general, avoiding activities that require a one-legged stance, such as bowling, skating, running, and using a stairstepper is helpful in alleviating symptoms. Correcting asymmetries in muscle length should start as soon as possible. This correction should be accomplished within the limits of pain. Muscle energy techniques are particularly helpful because they require the patient to activate muscle groups, and therefore pain tolerance is easily monitored. Special care should be taken with early treatment of the pregnant athlete or exerciser. Because of the usual hypermobility associated with pregnancy, stretching or mobilization that is too aggressive can further aggravate her symptoms.

**Recovery Phase (3 Days to 8 Weeks).** Once pain has been controlled and the injured area has been rested, correction of the functional biomechanical deficit and tissue overload complex becomes the focus of rehabilitation. Balancing lower extremity muscle length and strength is important because they have both direct and indirect effects on the ilium and sacrum. Muscle length must first be restored. The iliopsoas commonly is found to be activating in a shortened position. This shortened position leads to an anteriorly rotated ilium. Hamstring strengthening cannot be accomplished until the iliopsoas is stretched. An anterior pelvic tilt forces the hamstring to work in a lengthened position. The hamstring is a key muscle to provide stability to the SIJ because of its direct attachment and fascial connections to the sacrotuberous ligament. Other muscles commonly found to be working in a shortened position include the rectus femoris, tensor fascia lata, adductors, quadratus lumborum, latissimus dorsi,<sup>12</sup> and obturator internus. Achieving appropriate muscle flexibility may require several weeks of stretching two to three times per day. Once appropriate muscle flexibility has been achieved, strengthening of muscles that are inhibited by the biomechanical deficit can be completed. Neuromuscular reeducation and facilitation techniques are helpful with this process. Closed kinetic chain strengthening should be attempted first and is incorporated into the lumbopelvic stabilization exercises. Muscles commonly found to be weak include the gluteus medius, gluteus maximus, lower abdominals, and hamstrings.

SIJ belts can be used to provide compression and thereby proprioceptive feedback to the gluteal muscles (Fig. 11). The author finds SIJ belts especially helpful in patients with hypermobility or significant muscle weakness. Care must be taken to ensure that the patient is able to apply the belt appropriately. The belt should be secured posteriorly across the sacral base and anteriorly, inferior to the anterior superior iliac spines.

Other equipment such as orthotics and shoe modification must be assessed. A shoe lift to correct a functional leg length discrepancy can be helpful in the acute setting to manage pain with weight bearing or walking. Further use of the shoe lift should be approached with caution, because the functional leg length discrepancy should be corrected with muscle rebalancing. An inappropriate shoe lift can promote a subclinical adaptation complex. Of course, anatomic leg length discrepancies should be determined as early in treatment as possible so that the appropriate modifications can be completed.

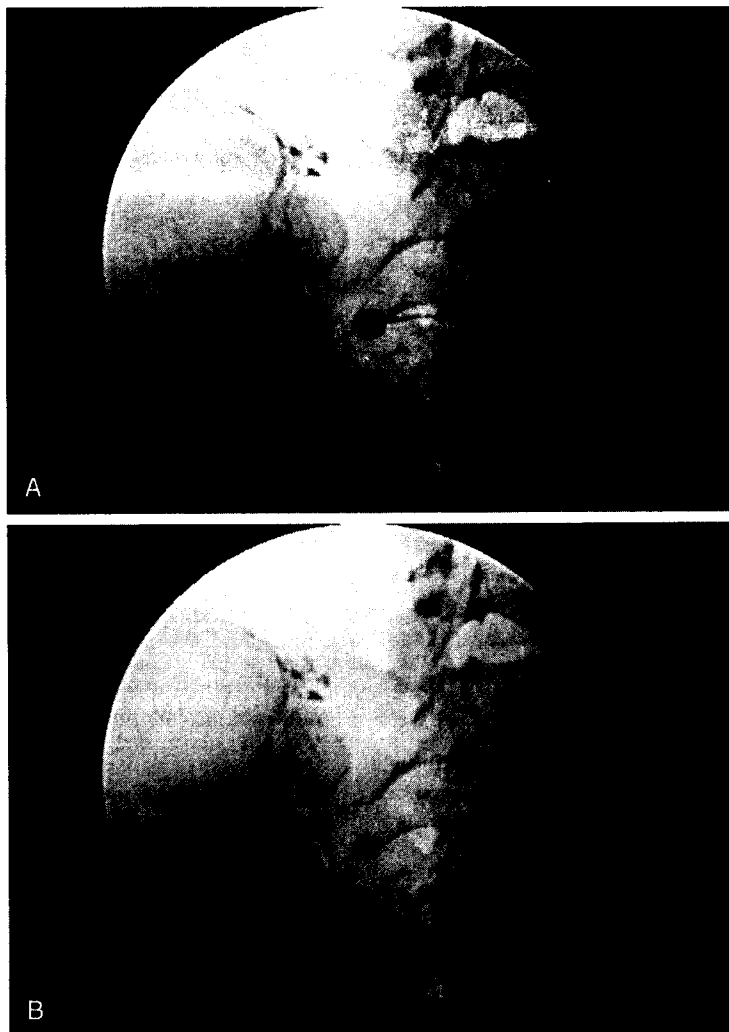
SIJ injections can be used as an adjunct to a physical therapy program if the athlete reaches a plateau or the program cannot be advanced because of pain provocation. The injections can be used diagnostically if done under fluoroscopic guidance (Fig. 12). Maigne and colleagues<sup>23</sup> reported 18.5% of 54 patients diagnosed with SIJ pain responded to double SIJ block under fluoroscopic guidance.



**Figure 11.** SIJ belt used to facilitate joint compression and proprioceptive feedback to gluteal muscles.

This study did not control for other treatments given and therefore accurately reports only what an injection alone can improve. Progression to the maintenance phase of treatment includes absence of pain and inflammation, absence of functional joint and myofascial dysfunction, and return of approximately 75% of strength and flexibility as judged by the patient's preinjury baseline. Normal activities of daily living, especially walking, should not provoke symptoms.

**Maintenance Phase.** During the maintenance phase of rehabilitation, the focus turns to correcting the biomechanical deficits and the functional adaptation complex. Recognizing the adaptations that have occurred in response to the injury is essential to prevent further injury when the athlete returns to sport participation. A common example includes the role of the gluteus maximus to stabilize the pelvis posteriorly by means of attachments at the ilium and sacrotuberous ligament. If the SIJ dysfunction involves an anteriorly rotated ilium, correction of the inflexibility of the iliopsoas alone will be insufficient. If the gluteus maximus contractions are too weak to stabilize posteriorly, then stretch will be placed on the iliolumbar ligament as well. This stretch, in turn, will lead to lower lumbar segmental restrictions that must be addressed during the treatment process. The piriformis muscle length should be assessed with the hip flexed greater and less than 90 degrees. Stretching applied with the hip in either or both directions is necessary. Continued inflexibility of this muscle is often thought to be part of the source of recurrent pain. Though maintaining individual muscle flexibility and strength is important, retraining of multiple muscle groups to fire in coordination is focused on during this phase in rehabilitation. Coordination of muscle firing can be facilitated with lumbopelvic stabilization, advanced proprioceptive reeducation, pyelometrics, and exercise- or sport-specific activities. Education regarding proper ergonomics in activities of daily living and work environment should be included. Careful attention to training techniques must be incorporated into the program. Mechanics are reviewed with return to exercise activity to rule out break down in the stabilization



**Figure 12.** Fluoroscopically guided SIJ injection has both diagnostic and therapeutic benefits.

that has just been completed. Return to sport or exercise routine should resume when the athlete is pain-free without medications. Proper muscle balance in flexibility and strength should remain a part of the maintenance program. Careful monitoring during initial return can prevent reinjury.

SIJ hypermobility that is unresponsive to the program first described is a difficult problem. SIJ arthrodesis is proposed for instability. Long-term outcome studies thus far have not been completed, and it is unknown what happens to surrounding articulations with the lumbar spine, contralateral SIJ, and hip.

Prolotherapy has been proposed as an invasive but less permanent option in such cases. This treatment is supported by the theory that stimulation of fibrosis by needling a ligament followed by infusion of sclerosing agent will stabilize ligamentous laxity. No prospective, controlled studies exist to date on the specific use of prolotherapy and SIJ dysfunction.

### Muscle Strains Involving the Groin

**Acute Phase (1 to 3 Days).** Muscles most often involved in groin strains injury include the adductor longus at the proximal musculotendinous junction, tendon to osseus insertion onto the inferior pubic tubercle, or muscle belly. During the acute stage, ice and relative rest are important. The athlete or exerciser should avoid repeated hip abduction or resisted hip adduction. If pain is significant with weight bearing, crutches may be necessary to facilitate pain control. Stretching during this stage should be limited to a pain-free range of motion. Modalities such as ice and electrical stimulation may be used as adjuncts to pain management. Antiinflammatory medications can also help relieve edema and facilitate pain management.

**Recovery Phase (3 Days to 6 Weeks).** Again during this phase, the focus of rehabilitation turns to correcting the biomechanical deficits and tissue overload complex. Modalities and medications may be continued during the first few weeks for adequate pain management. Active range of motion is advanced in the pain-free range. Myofascial release and muscle energy techniques may further promote increased range of motion. The patient should be independent in self-stretching, pelvic tilts, and concentric contraction of the antagonistic hip abductors. Four to six weeks after injury superficial heat and ultrasound may further expedite muscle stretching. Strengthening is added during this phase. Initially stretching should be limited to multilevel isometric exercise within a pain-free range. Proprioceptive reeducation can be added with balance retraining. Care should be taken to monitor the position of the pubic symphysis during this phase. Muscle shortening or instability may be recognized because of difference in pubic symphysis heights and rotation on palpation. Muscle energy techniques can be useful in correcting this dysfunction. The patient can become independent in self-correction. Retraining proper sequence of firing of hip abductors is important. Balance must be achieved between the contraction of usually weak lower abdominal muscles and tight hip adductors. The latter address the functional adaptation complex. The patient advances to the maintenance phase when pain and inflammation are controlled. Range of motion should be pain-free and symmetric on side-to-side comparison. There should be no limitation in activities of daily living, including walking, and no recurrent pubic symphysis dysfunction.

**Maintenance Phase.** During the maintenance phase the functional biomechanical deficit continues to be addressed through stretching and strengthening of the adductor muscle group. Attention to the tissue overload complex is begun with avoidance of excessive strain and inflammation to the lateral hip and pelvic structures. In particular, avoidance of tensor fascia lata overuse is enforced. Continued stabilization concentrates on coordinated lower abdominal contraction with the adductor group. Resistance can be added to the stabilization program with graduated weights. Before weight training for hip abduction is initiated, proper sequence of muscle contraction should be noted. If not, the tensor fascia lata will continue to be strengthened and the adductors will con-



tinue to be inhibited. In addition to advancing walking and running, kicking mechanics should be reviewed.

### Prehabilitation

As healthcare providers direct their treatment plans toward restoration of function after an injury, more will be understood about what is necessary to develop an appropriate prehabilitation program. Prehabilitation is based on the individual's needs regarding restoration and education of appropriate mechanics. The individual athlete's needs are then taken into account when applying sport-specific training techniques. Advancing a training program's intensity, duration, and repetitions should not be a cookbook formulary. Instead, progression of the training program should coincide with the individual's capability of performing the activity with proper mechanics. This technique potentially could prevent subsequent overuse injuries. With regard to the hip and pelvis, prevention of injury should focus on the assurance of proper joint mechanics and balanced muscle flexibility and strength. This balance is an evolving process with aging.

Women in particular have life cycle changes that affect musculoskeletal function. As adolescents, some girls are prone to joint hypermobility and laxity, which places them at increased risk for injury. During the early adult years, trauma to the pelvic floor as a result of childbirth can place the woman at increased risk for pelvic floor pain, pelvic pain, and urinary incontinence. Some of these dysfunctions may be subtle and become clinically relevant when the woman returns to exercise or sport participation. With middle age, hormonal changes may facilitate soft-tissue atrophy and soften bones, placing the woman at increased risk for overuse injuries. Surgeries involving the pelvis such as hysterectomies and bladder suspensions place the woman at risk for developing pelvic floor pain dysfunctions. Degenerative changes begin and may limit joint motion with subsequent loss in muscle flexibility. Some of these changes may cause symptoms only when the woman increases or changes her activity level. Adapting training and exercise prescriptions to the individual is important. Taking into account where the woman is in the life cycle of aging and hormonal changes is vital.

Men acquire adaptive changes with aging as well. Loss of motion at the SIJ and hip occur with regularity. The lumbar spine or hip may attempt to make up for the loss of motion at the pelvis. Adaptive patterns ensue and bring additive risk for injury. Elderly men with metabolic disease are susceptible to loss of bone mass. Care should be taken in ruling out fracture in elderly athletes.

Both male and female athletes should work to maintain appropriate muscle activation sequences with functional activities. An example includes eliminating early lumbar erector spina activation with hip extension. The appropriate sequence can be accomplished only if the muscles about the hip and pelvis remain balanced between length and strength. Focusing on muscles that have a tendency to be tight (i.e., the iliopsoas) or inhibited (i.e., gluteus medius) is important in preventing overuse injuries at the pelvis.

Healthcare providers can assist coaches and parents in developing appropriate flexibility, strengthening, and balance training regimens to be implemented as part of the athletes' training program. Then, if an injury does occur, a rehabilitation program can be more easily implemented because the athlete is already familiar with the concepts of muscle activation in appropriate firing

patterns with appropriate length and strength. This knowledge would potentially lead to fewer athletes sidelined because of injury.

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